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THE INSTITUTION

OF

MECHANICAL ENGINEERS.

ESTABLISHED 1847.

PROCEEDINGS.

1900.

PARTS 1-2.

50727
1901

PUBLISHED BY THE INSTITUTION,
STOREY'S GATE, ST. JAMES'S PARK, WESTMINSTER, S.W.

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PAST-PRESIDENTS.

George Stephenson, 1847–48. (*Deceased* 1848.)

Robert Stephenson, F.R.S., 1849–53. (*Deceased* 1859.)

Sir William Fairbairn, Bart., LL.D., F.R.S., 1854–55. (*Deceased* 1874.)

Sir Joseph Whitworth, Bart., D.C.L., LL.D., F.R.S., 1856–57, 1866. (*Deceased* 1887.)

John Penn, F.R.S., 1858–59, 1867–68. (*Deceased* 1878.)

James Kennedy, 1860. (*Deceased* 1886.)

The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S., 1861–62, 1869.

Robert Napier, 1863–65. (*Deceased* 1876.)

John Ramsbottom, 1870–71. (*Deceased* 1897.)

Sir William Siemens, D.C.L., LL.D., F.R.S., 1872–73. (*Deceased* 1883.)

Sir Frederick J. Bramwell, Bart., D.C.L., LL.D., F.R.S., 1874–75.

Thomas Hawksley, F.R.S., 1876–77. (*Deceased* 1893.)

John Robinson, 1878–79.

Edward A. Cowper, 1880–81. (*Deceased* 1893.)

Percy G. B. Westmacott, 1882–83.

Sir Lowthian Bell, Bart., F.R.S., 1884.

Jeremiah Head, 1885–86. (*Deceased* 1899.)

Sir Edward H. Carbutt, Bart., 1887–88.

Charles Cochrane, 1889. (*Deceased* 1898.)

Joseph Tomlinson, 1890–91. (*Deceased* 1894.)

Sir William Anderson, K.C.B., D.C.L., F.R.S., 1892–93. (*Deceased* 1898.)

Alexander B. W. Kennedy, LL.D., F.R.S., 1894–95.

E. Windsor Richards, 1896–97.

Samuel Waite Johnson, 1898.

The Institution of Mechanical Engineers.

OFFICERS.

1900.

PRESIDENT.

Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S.,	London.

PAST-PRESIDENTS.

The Rt. Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S.,	Newcastle-on-Tyne.
Sir Lowthian Bell, Bart., F.R.S.,	Northallerton.
Sir Frederick J. Bramwell, Bart., D.C.L., LL.D., F.R.S.,	London.
Sir Edward H. Carbutt, Bart.,	London.
Samuel Waite Johnson,	Derby.
Alexander B. W. Kennedy, LL.D., F.R.S.,	London.
E. Windsor Richards,	Caerleon.
John Robinson,	Leek.
Percy G. B. Westmacott,	Ascot.

VICE-PRESIDENTS.

John A. F. Aspinall,	Manchester.
Arthur Keen,	Birmingham.
Edward P. Martin,	Dowlais.
William H. Maw,	London.
T. Hurry Riches,	Cardiff.
J. Hartley Wicksteed,	Leeds.

MEMBERS OF COUNCIL.

Sir William Arrol, M.P., LL.D.,	Glasgow.
Sir Benjamin Baker, K.C.M.G., LL.D., F.R.S.,	London.
Henry Chapman,	London.
Henry Davey,	London.
William Dean,	Swindon.
Bryan Donkin,	London.
Edward B. Ellington,	London.
H. Graham Harris,	London.
Henry A. Ivatt,	Doncaster.
Henry D. Marshall,	Gainsborough.
The Right Hon. William J. Pirrie, LL.D.	Belfast.
Samuel R. Platt,	Oldham.
Sir Thomas Richardson, M.P.,	Hartlepool.
John I. Thornycroft, F.R.S.,	London.
A. Tannett Walker,	Leeds.

TREASURER.

Harry Lee Millar.

SECRETARY.

Edgar Worthington,

The Institution of Mechanical Engineers, Storey's Gate, St. James's Park,
Westminster, S.W.

Telegraphic address:—*Mech, London.* Telephone:—*Westminster*, 264.

THE INSTITUTION OF MECHANICAL ENGINEERS.

Memorandum of Association.

AUGUST 1878.

1st. The name of the Association is "THE INSTITUTION OF MECHANICAL ENGINEERS."

2nd. The Registered Office of the Association will be situate in England.

3rd. The objects for which the Association is established are:—

(A.) To promote the science and practice of Mechanical Engineering and all branches of mechanical construction, and to give an impulse to inventions likely to be useful to the Members of the Institution and to the community at large.

(B.) To enable Mechanical Engineers to meet and to correspond, and to facilitate the interchange of ideas respecting improvements in the various branches of mechanical science, and the publication and communication of information on such subjects.

(C.) To acquire and dispose of property for the purposes aforesaid.

(D.) To do all other things incidental or conducive to the attainment of the above objects or any of them.

4th. The income and property of the Association, from whatever source derived, shall be applied solely towards the promotion of the objects of the Association as set forth in this Memorandum of Association, and no portion thereof shall be paid or transferred directly or indirectly, by way of dividend, bonus, or otherwise howsoever, by way of profit to the persons who at any time are or have been Members of the Association, or to any of them, or to any person claiming through any of them: Provided that nothing herein contained shall prevent the payment in good faith of remuneration to any officers or servants of the Association, or to any Member of the Association, or other person, in return for any services rendered to the Association, or prevent the giving of privileges to the Members of the Association in attending the meetings of the Association, or prevent the borrowing of money (under such powers as the Association and the Council thereof may possess) from any Member of the Association, at a rate of interest not greater than five per cent. per annum.

5th. The fourth paragraph of this Memorandum is a condition on which a licence is granted by the Board of Trade to the Association in pursuance of Section 23 of the Companies Act 1867. For the purpose of preventing any evasion of the terms of the said fourth paragraph, the Board of Trade may from time to time, on the application of any Member of the Association, impose further conditions, which shall be duly observed by the Association.

6th. If the Association act in contravention of the fourth paragraph of this Memorandum, or of any such further conditions, the liability of every Member of the Council shall be unlimited; and the liability of every Member of the Association who has received any such dividend, bonus, or other profit as aforesaid, shall likewise be unlimited.

7th. Every Member of the Association undertakes to contribute to the Assets of the Association in the event of the same being wound up during the time that he is a Member, or within one year afterwards, for payment of the debts and liabilities of the Association contracted before the time at which he ceases to be a Member, and of the costs, charges, and expenses for winding up the same, and for the adjustment of the rights of the contributories amongst themselves, such amount as may be required not exceeding Five Shillings, or in case of his liability becoming unlimited such other amount as may be required in pursuance of the last preceding paragraph of this Memorandum.

8th. If upon the winding up or dissolution of the Association there remains, after the satisfaction of all its debts and liabilities, any property whatsoever, the same shall not be paid to or distributed among the Members of the Association, but shall be given or transferred to some other Institution or Institutions having objects similar to the objects of the Association, to be determined by the Members of the Association at or before the time of dissolution ; or in default thereof, by such Judge of the High Court of Justice as may have or acquire jurisdiction in the matter.

Articles of Association.

February 1893.

INTRODUCTION.

Whereas an Association called "The Institution of Mechanical Engineers" existed from 1847 to 1878 for objects similar to the objects expressed in the Memorandum of Association of the Association (hereinafter called "the Institution") to which these Articles apply;

And whereas the Institution was formed in 1878 for furthering and extending the objects of the former Institution, by a registered Association, under the Companies Acts 1862 and 1867;

And whereas terms used in these Articles are intended to have the same respective meanings as they have when used in those Acts, and words implying the singular number are intended to include the plural number, and *vice versâ*;

Now therefore it is hereby agreed as follows:—

CONSTITUTION.

1. For the purpose of registration the number of members of the Institution is unlimited.

MEMBERS, ASSOCIATE MEMBERS, GRADUATES, ASSOCIATES, AND HONORARY LIFE MEMBERS.

2. The present Members of the Institution, and such other persons as shall be admitted in accordance with these Articles, and none others, shall be Members of the Institution, and be entered on the register as such.

3. Any person may become a Member of the Institution who shall be qualified and elected as hereinafter mentioned, and shall agree to become such Member, and shall pay the entrance fee and first subscription accordingly.

4. The qualification of Members shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

5. The election of Members shall be conducted as prescribed by the By-laws from time to time in force, as provided by the Articles.

6. In addition to the persons already admitted as Graduates, Associates, and Honorary Life Members respectively, the Institution may admit such persons as may be qualified and elected in that behalf as Associate Members, Graduates, Associates, and Honorary Life Members respectively of the Institution, and may confer upon them such privileges as shall be prescribed by the By-laws from time to time in force, as provided by the Articles: provided that no Associate Member, Graduate, Associate, or Honorary Life Member shall be deemed to be a Member within the meaning of the Articles.

7. The qualification and mode of election of Associate Members, Graduates, Associates, and Honorary Life Members shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

8. The rights and privileges of every Member, Associate Member, Graduate, Associate, or Honorary Life Member shall be personal to himself, and shall not be transferable or transmissible by his own act or by operation of law.

ENTRANCE FEES AND SUBSCRIPTIONS.

9. The Entrance Fees and Subscriptions of Members, Associate Members, Graduates, and Associates shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

EXPULSION.

10. If any Member, Associate Member, Graduate, or Associate shall leave his subscription in arrear for two years, and shall fail to pay such arrears within three months after a written application has been sent to him by the Secretary, his name may be struck off the register by the Council at any time afterwards, and he shall thereupon cease to have any rights as a Member, Associate Member, Graduate, or Associate, but he shall nevertheless continue liable to pay the arrears of subscription due at the time of his name being so struck off: provided always that this regulation shall not be construed to compel the Council to remove any name, if they shall be satisfied the same ought to be retained.

11. The Council may refuse to continue to receive the subscriptions of any person who shall have wilfully acted in contravention of the regulations of the Institution, or who shall in the opinion of the Council have been guilty of such conduct as shall have rendered him unfit to continue to belong to the Institution; and may remove his name from the register, and he shall thereupon cease to be a Member, Associate Member, Graduate, or Associate (as the case may be) of the Institution.

GENERAL MEETINGS.

12. The General Meetings shall consist of the Ordinary Meetings, the Annual General Meeting, and of Special Meetings as hereinafter defined.

13. The Annual General Meeting shall take place in London in one of the first four months of every year. The Ordinary Meetings shall take place at such times and places as the Council shall determine.

14. A Special Meeting may be convened at any time by the Council, and shall be convened by them whenever a requisition signed by twenty Members or Associate Members of the Institution,

specifying the object of the Meeting, is left with the Secretary. If for fourteen days after the delivery of such requisition a Meeting be not convened in accordance therewith, the Requisitionists or any twenty Members or Associate Members of the Institution may convene a Special Meeting in accordance with the requisition. All Special Meetings shall be held in London.

15. Seven clear days' notice of every Meeting, specifying generally the nature of any special business to be transacted at any Meeting, shall be given to every person on the register of the Institution, except as provided by Article 35, and no other special business shall be transacted at such Meeting; but the non-receipt of such notice shall not invalidate the proceedings of such Meeting. No notice of the business to be transacted (other than such ballot lists as may be requisite in case of elections) shall be required in the absence of special business.

16. Special business shall include all business for transaction at a Special Meeting, and all business for transaction at every other Meeting, with the exception of the reading and confirmation of the Minutes of the previous Meeting, the election of Members, Associate Members, Graduates, and Associates, and the reading and discussion of communications as prescribed by the By-laws, or by any regulations of the Council made in accordance with the By-laws.

PROCEEDINGS AT GENERAL MEETINGS.

17. Twenty Members or Associate Members shall constitute a quorum for the purpose of a Meeting other than a Special Meeting. Thirty Members or Associate Members shall constitute a quorum for the purpose of a Special Meeting.

18. If within thirty minutes after the time fixed for holding the Meeting a quorum is not present, the Meeting shall be dissolved, and all matters which might, if a quorum had been present, have been done at a Meeting (other than a Special Meeting) so dissolved, may forthwith be done on behalf of the Meeting by the Council.

19. The President shall be Chairman at every Meeting, and in his absence one of the Vice-Presidents; and in the absence of all Vice-Presidents a Member of Council shall take the chair; and if no Member of Council be present and willing to take the chair, the Meeting shall elect a Chairman.

20. The decision of a General Meeting shall be ascertained by show of hands, unless, after the show of hands, a poll is forthwith demanded; and by a poll, when a poll is thus demanded. The manner of taking a show of hands or a poll shall be in the discretion of the Chairman; and an entry in the Minutes, signed by the Chairman, shall be sufficient evidence of the decision of the General Meeting. Each Member and Associate Member shall have one vote and no more. In case of equality of votes the Chairman shall have a second or casting vote: provided that this Article shall not interfere with the provisions of the By-laws as to election by ballot.

21. The acceptance or rejection of votes by the Chairman shall be conclusive for the purpose of the decision of the matter in respect of which the votes are tendered: provided that the Chairman may review his decision at the same Meeting, if any error be then pointed out to him.

BY-LAWS.

22. The By-laws set forth in the schedule to these Articles, and such altered and additional By-laws as shall be substituted or added as hereinafter mentioned, shall regulate all matters by the Articles left to be prescribed by the By-laws, and all matters which consistently with the Articles shall be made the subject of By-laws. Alterations in, and additions to, the By-laws, may be made only by resolution of the Members and Associate Members at an Annual General Meeting, after notice of the proposed alteration or addition has been announced at the previous Ordinary Meeting, and not otherwise.

COUNCIL.

23. The Council of the Institution shall be chosen from the Members only, and shall consist of one President, six Vice-Presidents, fifteen ordinary Members of Council, and of the Past-Presidents. The President, two Vice-Presidents, and five Members of Council (other than Past-Presidents), shall retire at each Annual General Meeting, but shall be eligible for re-election. The Vice-Presidents and Members of Council to retire each year shall, unless the Council agree among themselves, be chosen from those who have been longest in office, and in cases of equal seniority shall be determined by ballot.

24. The election of a President, Vice-Presidents, and Members of Council, to supply the place of those retiring at the Annual General Meeting, shall be conducted in such manner as shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

25. The Council may supply any casual vacancy in the Council (including any casual vacancy in the office of President) which shall occur between one Annual General Meeting and another; and the President, Vice-Presidents, or Members of Council so appointed by the Council shall retire at the succeeding Annual General Meeting. Vacancies not filled up at any such Meeting shall be deemed to be casual vacancies within the meaning of this Article.

OFFICERS.

26. The Treasurer, Secretary, and other employés of the Institution shall be appointed and removed in the manner prescribed by the By-laws from time to time in force, as provided by the Articles. Subject to the express provisions of the By-laws, the officers and servants of the Institution shall be appointed and removed by the Council.

27. The powers and duties of the officers of the Institution shall, subject to any express provision in the By-laws, be determined by the Council.

POWERS AND PROCEDURE OF COUNCIL.

28. The Council may regulate their own procedure, and delegate any of their powers and discretions to any one or more of their body, and may determine their own quorum: if no other number is prescribed, three members of Council shall form a quorum.

29. The Council shall manage the property, proceedings, and affairs of the Institution, in accordance with the By-laws from time to time in force.

30. The Treasurer may, with the consent of the Council, invest in the name of the Institution any moneys not immediately required for the purposes of the Institution in or upon any of the following investments (that is to say):—

(A) The Public Funds, or Government Stocks of the United Kingdom, or of any Foreign or Colonial Government guaranteed by the Government of the United Kingdom.

(B) Real or Leasehold Securities, or in the purchase of real or leasehold properties in Great Britain or Ireland.

(C) Debentures, Debenture Stock, or Guaranteed or Preference Stock, of any Company incorporated by special Act of Parliament, the ordinary Shareholders whereof shall at the time of such investment be in actual receipt of half-yearly or yearly dividends.

(D) Stocks, Shares, Debentures, or Debenture Stock of any Railway, Canal, or other Company, the undertaking whereof is leased to any Railway Company at a fixed or fixed minimum rent.

(E) Stocks, Shares, or Debentures of any East Indian Railway or other Company, which shall receive a contribution from Her Majesty's East Indian Government of a fixed annual percentage on their capital, or be guaranteed a fixed annual dividend by the same Government.

(F) The security of rates levied by any corporate body empowered to borrow money on the security of rates, where such borrowing has been duly authorised by Act of Parliament.

31. The Council may, with the authority of a resolution of the Members and Associate Members in General Meeting, borrow moneys for the purposes of the Institution on the security of the property of the Institution, or otherwise at their discretion.

32. No act done by the Council, whether *ultra vires* or not, which shall receive the express or implied sanction of the Members and Associate Members in General Meeting, shall be afterwards impeached by any member of the Institution on any ground whatsoever, but shall be deemed to be an act of the Institution.

NOTICES.

33. A notice may be served by the Council upon any Member, Associate Member, Graduate, Associate, or Honorary Life Member, either personally or by sending it through the post in a prepaid letter addressed to him at his registered place of abode.

34. Any notice, if served by post, shall be deemed to have been served at the time when the letter containing the same would be delivered in the ordinary course of the post; and in proving such service it shall be sufficient to prove that the letter containing the notice was properly addressed and put into the post office.

35. No Member, Associate Member, Graduate, Associate, or Honorary Life Member, not having a registered address within the United Kingdom, shall be entitled to any notice; and all proceedings may be had and taken without notice to such member, in the same manner as if he had had due notice.

By-laws.

(*Last Revision, February* 1894.)

MEMBERSHIP.

1. Candidates for admission as Members must be persons not under twenty-five years of age, who, having occupied during a sufficient period a responsible position in connection with the practice or science of Engineering, may be considered by the Council to be qualified for election.

2. Candidates for admission as Associate Members must be persons not under twenty-five years of age, who, being engaged in such work as is connected with the practice or science of Engineering, may be considered by the Council to be qualified for election, though not yet to occupy positions of sufficient responsibility, or otherwise not yet to be eligible, for admission as Members. They may afterwards be transferred at the discretion of the Council to the class of Members.

3. Candidates for admission as Graduates must be persons holding subordinate situations, and not under eighteen years of age. They must furnish evidence of training in the principles as well as in the practice of Engineering. Before attaining the age of twenty-six years, those elected after 1892 must apply for election as Members, Associate Members, or Associates, if they desire to remain connected with the Institution; they may not continue Graduates after attaining the age of twenty-six.

4. Candidates for admission as Associates must be persons not under twenty-five years of age, who from their scientific attainments or position in society may be considered eligible by the Council. They may afterwards be transferred at the discretion of the Council to the class of Associate Members or of Members.

5. The Council shall have the power to nominate as Honorary Life Members persons of eminent scientific acquirements, who in their opinion are eligible for that position.

6. The Members, Associate Members, Graduates, Associates, and Honorary Life Members shall have notice of and the privilege to attend all Meetings; but Members and Associate Members only shall be entitled to vote thereat.

7. The abbreviated distinctive Titles for indicating the connection with the Institution of Members, Associate Members, Graduates, Associates, or Honorary Life Members thereof, shall be the following:—for Members, M. I. Mech. E.; for Associate Members, A. M. I. Mech. E.; for Graduates, G. I. Mech. E.; for Associates, A. I. Mech. E.; for Honorary Life Members, Hon. M. I. Mech. E.

8. Subject to such regulations as the Council may from time to time prescribe, any Member, Associate Member, or Associate may upon application to the Secretary obtain a Certificate of his membership or other connection with the Institution. Every such certificate shall remain the property of, and shall on demand be returned to, the Institution.

ENTRANCE FEES AND SUBSCRIPTIONS.

9. Each Member shall pay an Annual Subscription of £3, and on election an Entrance Fee of £2.

10. Each Associate Member shall pay an Annual Subscription of £2 10*s.*, and on election an Entrance Fee of £1. If afterwards transferred by the Council to the class of Members, he shall pay on transference 10*s.* additional subscription for the current year, and £1 additional entrance fee.

11. Each Graduate shall pay an Annual Subscription of £1 10*s.*, but no Entrance Fee. Any Graduate elected prior to 1893, if transferred by the Council to the class of Associate Members, shall pay on transference £1 additional subscription for the current year, but no additional entrance fee; if transferred direct to the class of Members, he shall pay on transference £1 10*s.* additional subscription for the current year, and £1 additional entrance fee.

12. Each Associate shall pay an Annual Subscription of £2 10*s.*, and on election an Entrance Fee of £1. If afterwards transferred by the Council to the class of Associate Members, he shall pay on transference no additional subscription or entrance fee. If transferred direct to the class of Members, he shall pay on transference 10*s.* additional subscription for the current year, and £1 additional entrance fee; except Associates elected prior to 1893, who shall pay no additional entrance fee on transference.

13. All subscriptions shall be payable in advance, and shall become due on the 1st day of January in each year; and the first subscription of Members, Associate Members, Graduates, and Associates, shall date from the 1st day of January in the year of their election.

14. In the case of Members, Associate Members, Graduates, or Associates, elected in the last three months of any year, the first subscription shall cover both the year of election and the succeeding year.

15. Any Member, Associate Member, or Associate, whose subscription is not in arrear, may at any time compound for his subscription for the current and all future years by the payment of Fifty Pounds, if paid in any one of the first five years of his membership. If paid subsequently, the sum of Fifty Pounds shall be reduced by One Pound per annum for every year of membership after five years. All compositions shall be deemed to be capital moneys of the Institution.

16. The Council may at their discretion reduce or remit the annual subscription, or the arrears of annual subscription, of any Member or Associate Member who shall have been a subscribing member of the Institution for twenty years, and shall have become unable to continue the annual subscription provided by these By-laws.

17. No Proceedings or Ballot Lists or Certificates shall be sent to Members, Associate Members, Graduates, or Associates, who are in

arrear with their subscriptions more than twelve months, and whose subscriptions have not been remitted by the Council as hereinbefore provided.

ELECTION OF MEMBERS, ASSOCIATE MEMBERS, GRADUATES, AND ASSOCIATES.

18. A recommendation for admission according to Form A or B in the Appendix shall be forwarded to the Secretary, and by him be laid before the next Meeting of the Council. The recommendation must be signed by not less than five Members or Associate Members if the application be for admission as a Member or Associate Member or Associate, and by three Members or Associate Members if it be for a Graduate.

19. All elections shall take place by ballot, four-fifths of the votes given being necessary for election.

20. All applications for admission shall be communicated by the Secretary to the Council for their approval previous to being inserted in the ballot list for election, and the approved ballot list shall be signed by the President and forwarded to the Members and Associate Members. The name of any Candidate approved by the Council for admission as an Associate Member or an Associate shall not be inserted in the ballot list until he has signed the Form C in the Appendix. The ballot list shall specify the name, occupation, and address of the Candidates, and also by whom proposed and seconded. The lists shall be opened only in the presence of the Council on the day of election, by a Committee to be appointed for that purpose.

21. The Elections shall take place at the General Meetings only.

22. When the proposed Candidate is elected, the Secretary shall give him notice thereof according to Form D; but his name shall not be added to the register of the Institution until he shall have paid his Entrance Fee and first Annual Subscription, and signed the Form E in the Appendix.

23. In case of non-election, no mention thereof shall be made in the Minutes, nor any notice given to the unsuccessful Candidate.

24. An Associate Member desirous of being transferred to the class of Members, or an Associate to the class of Associate Members or of Members, shall forward to the Secretary a recommendation according to Form F in the Appendix, signed by not less than five Members or Associate Members, which shall be laid before the next meeting of Council for their approval. On their approval being given, the Secretary shall notify the same to the Candidate according to Form G ; but his name shall not be added to the list of Members or Associate Members until he shall have signed the Form H, and shall have paid the additional entrance fee (if any), and the additional subscription (if any) for the current year.

ELECTION OF PRESIDENT, VICE-PRESIDENTS, AND MEMBERS OF COUNCIL.

25. Candidates shall be put in nomination at the General Meeting preceding the Annual General Meeting, when the Council are to present a list of their retiring Members who offer themselves for re-election; any Member or Associate Member shall then be entitled to add to the list of Candidates. The ballot list of the proposed names shall be forwarded to the Members and Associate Members. The ballot lists shall be opened only in the presence of the Council on the day of election, by a Committee to be appointed for that purpose.

APPOINTMENT AND DUTIES OF OFFICERS.

26. The Treasurer shall be a Banker, and shall hold the uninvested funds of the Institution, except the moneys in the hands of the Secretary for current expenses. He shall be appointed by the Members and Associate Members at a General or Special Meeting, and shall hold office at the pleasure of the Council.

27. The Secretary of the Institution shall be appointed, as and when a vacancy occurs, by the Members and Associate Members at a General or Special Meeting, and shall be removable by the Council upon six months' notice from any day. The Secretary shall give the same notice. The Secretary shall devote the whole of his time to the work of the Institution, and shall not engage in any other business or profession.

28. It shall be the duty of the Secretary, under the direction of the Council, to conduct the correspondence of the Institution; to attend all meetings of the Institution, and of the Council, and of Committees; to take minutes of the proceedings of such meetings; to read the minutes of the preceding meetings, and all communications that he may be ordered to read; to superintend the publication of such papers as the Council may direct; to have the charge of the library; to direct the collection of the subscriptions, and the preparation of the account of expenditure of the funds; and to present all accounts to the Council for inspection and approval. He shall also engage (subject to the approval of the Council) and be responsible for all persons employed under him, and set them their portions of work and duties. He shall conduct the ordinary business of the Institution, in accordance with the Articles and By-laws and the directions of the President and Council; and shall refer to the President in any matters of difficulty or importance, requiring immediate decision.

MISCELLANEOUS.

29. All Papers shall be submitted to the Council for approval, and after their approval shall be read by the Secretary at the General Meetings, or by the Author with the consent of the Council; or, if so directed by the Council, shall be printed in the Proceedings without having been read at a General Meeting.

30. All books, drawings, communications, &c., shall be accessible to the members of the Institution at all reasonable times.

31. All communications to the Meetings shall be the property of the Institution, and be published only by the authority of the Council.

32. None of the property of the Institution—books, drawings, &c.—shall be taken out of the premises of the Institution without the consent of the Council.

33. All donations to the Institution shall be enumerated in the Annual Report of the Council presented to the Annual General Meeting.

34. The General Meetings shall be conducted as far as practicable in the following order:—

1st. The Chair to be taken at such hour as the Council may direct from time to time.

2nd. The Minutes of the previous Meeting to be read by the Secretary, and, after being approved as correct, to be signed by the Chairman.

3rd. The Ballot Lists, previously opened by the Council, to be presented to the Meeting, and the new Members, Associate Members, Graduates, and Associates elected to be announced.

4th. Papers approved by the Council to be read by the Secretary, or by the Author with the consent of the Council.

35. Each Member or Associate Member shall have the privilege of introducing one friend to any of the Meetings; but, during such portion of any meeting as may be devoted to any business connected with the management of the Institution, visitors shall be requested by the Chairman to withdraw, if any Member or Associate Member asks that this shall be done.

36. Every Member, Associate Member, Graduate, Associate, or Visitor, shall write his name and residence in a book to be kept for the purpose, on entering each Meeting.

37. The President shall ex officio be member of all Committees of Council.

38. Seven clear days' notice at least shall be given of every meeting of the Council. Such notice shall specify generally the business to be transacted by the meeting. No business involving the expenditure of the funds of the Institution (except by way of payment of current salaries and accounts) shall be transacted at any Council meeting unless specified in the notice convening the meeting.

39. The Council shall present the yearly accounts to the Annual General Meeting, after being audited by a professional accountant, who shall be appointed annually by the Members and Associate Members at a General or a Special Meeting, at a remuneration to be then fixed by the Members and Associate Members.

40. Any member wishing to have a copy of the Papers sent to him for consideration beforehand can do so by sending in his name once in each year to the Secretary; and a copy of all Papers shall then be forwarded to him as early as possible prior to the date of the Meeting at which they are intended to be read.

41. At any Meeting of the Institution any member shall be at liberty to re-open the discussion upon any Paper which has been read or discussed at the preceding Meeting; provided that he signifies his intention to the Secretary at least one month previously to the Meeting, and that the Council decide to include it in the notice of the Meeting as part of the business to be transacted.

APPENDIX.

FORM A.

Mr. being years of age, and desirous of admission into The Institution of Mechanical Engineers, we, the undersigned proposer and seconder from our personal knowledge, and the three other signers from trustworthy information, propose and recommend him as a proper person to belong to the Institution.

Witness our hands, this day of

Members or Associate Members.

FORM B.

Mr. born on being desirous of admission into The Institution of Mechanical Engineers, we, the undersigned proposer and seconder from our personal knowledge, and the other signer or signers from trustworthy information, propose and recommend him as a proper person to become a Graduate thereof.

Witness our hands, this day of

Members or Associate Members.

FORM C.

If elected an of The Institution of Mechanical Engineers, I, the undersigned, do hereby engage to ratify my election by signing the form of agreement (E) and paying the Entrance Fee and Annual Subscription in conformity with the By-laws.

Witness my hand, this day of

FORM D.

Sir,—I have to inform you that on the you were elected a of The Institution of Mechanical Engineers. For the ratification of your election in conformity with the rules, it is requisite that the enclosed form be returned to me with your signature, and that your Entrance Fee and first Annual Subscription be paid, the amounts of which are and respectively. If these be not received within two months from the present date, the election will become void.

I am, Sir, Your obedient servant,

Secretary.

FORM E.

I, the undersigned, being elected a of The Institution of Mechanical Engineers, do hereby agree that I will be governed by the regulations of the said Institution, as they are now formed or as they may hereafter be altered; that I will advance the objects of the Institution as far as shall be in my power, and will attend the Meetings thereof as often as I conveniently can: provided that, whenever I shall signify in writing to the Secretary that I am desirous of withdrawing from the Institution, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, this day of

FORM F.

Mr. being years of age, and desirous of being transferred into the class of of The Institution of Mechanical Engineers, we, the undersigned, from our personal knowledge recommend him as a proper person to be so transferred by the Council.

Witness our hands, this day of

Members or Associate Members.

FORM G.

Sir,—I have to inform you that the Council have approved of your being transferred to the class of of The Institution of Mechanical Engineers. For the ratification of your transference in conformity with the rules, it is requisite that the enclosed form be returned to me with your signature, and that your additional Entrance Fee and additional Annual Subscription for the current year be paid, the amounts of which are and respectively. If these be not received within two months from the present date, the transference will become void.

I am, Sir, Your obedient servant,

Secretary.

FORM H.

I, the undersigned, having been transferred to the class of of The Institution of Mechanical Engineers, do hereby agree that I will be governed by the regulations of the said Institution, as they now exist, or as they may hereafter be altered; that I will advance the objects of the Institution as far as shall be in my power, and will attend the Meetings thereof as often as I conveniently can: provided that, whenever I shall signify in writing to the Secretary that I am desirous of withdrawing from the Institution, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, this day of

The Institution of Mechanical Engineers.

PROCEEDINGS.

JANUARY 1900.

The FIFTY-THIRD ANNUAL GENERAL MEETING of the Institution was held at Storey's Gate, St. James's Park, London, on Friday, 26th January 1900, at Eight o'clock p.m. Owing to the unavoidable absence of the President, Sir WILLIAM H. WHITE, K.C.B., the chair was taken by Sir EDWARD H. CARBUTT, Bart., Past-President.

The Minutes of the previous Meeting were read, approved, and signed by the Chairman.

The CHAIRMAN announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following one hundred and eleven candidates were found to be duly elected:—

MEMBERS.

ADAMSON, CHARLES JOHN, . . .	London.
AITON, JOHN ARTHUR, ...	London.
BENNIE, PETER, ...	Huelva, Spain.
BRAMSDON, WILLIAM HENRY, R.N., .	Mediterranean Squadron.
BREARLEY, FREDERICK THOMAS, . .	St. Helens, Lancs.
BUSHELL, EDWARD HUNTER, . . .	Liverpool.
CLARKSON, EDWARD JOSEPH, . . .	Granville, N. S. Wales.
COTTON, CHARLES CATHROW CARNE, .	London.
DENNY, JOHN, ...	Fremantle, W. Australia.
DRYDEN, ALBERT, ...	Calcutta.
DUDIN, HENRY WILLIAM, . . .	London.
ELMER, JOSEPH JOHN, ...	London.
FAVELL, THOMAS MILNES, . . .	Stoke-on-Trent.

Fox, Charles Heyland,	London.
Greaven, Andrew Augustine,	Buenos Aires.
Hepworth, John William,	Bombay.
Hill, Walter Scott, R.N.,	Pacific Station.
Hurst, Isaac Edwin, R.N.,	Mediterranean Squadron.
Iddon, James,	Leyland, Lancs.
Little, Edwin, R.N.,	Mediterranean Squadron.
Liversedge, Henry Thomas, R.N.,	Rochester.
Morrison, Gabriel James,	Shanghai.
Paterson, James Alverne, R.N.,	Australian Squadron.
Pendred, Vaughan,	London.
Sauvage, Edouard,	Paris.
Sheldon, William John,	São Paulo, Brazil.
Smart, Alexander,	Erith, Kent.
Smith, Alexander Dawson,	London.
Taylor, Charles Gerald, R.N.,	Halifax, Nova Scotia.
Thompson, John Robert,	New York.
Thomsett, Frank Dathan, R.N.,	East Indies Station.
Thomson, George,	Port Natal.
Thumwood, Lewis Edward, R.N.,	Australian Squadron.
Veen, Vernon Alfred Alexander ter, R.N.,	London.
Whale, George,	Crewe.
Wollaston, Thomas Roland,	Manchester.

ASSOCIATE MEMBERS.

Andrew, Samuel Ernest,	London.
Barty, Alexander Douglas,	Old Charlton, Kent.
Begbie, Sydney Dawson,	London.
Calderwood, William,	London.
Carter, Samuel Arthur,	Exeter.
Cluff, Richard,	London.
Coombs, James Alger,	Ruabon.
Cooper, William James,	Birmingham.
Ellington, Guy,	London.
Evans, Griffith Cooper,	London.

Furnivall, William Henry Graham,	Johannesburg.
Gaston, Alfred Benjamin,	Shanghai.
George, James MacNaughten,	Aberdeen.
Gibson, George Henry,	Glasgow.
Ginders, Ernest Marsh,	Birkenhead.
Goodman, Alfred Christian,	Birmingham.
Greene, Frank Arnold,	London.
Griffiths, William John,	London.
Grimley, William Richard Nash,	London.
Haughton, George Bayly,	London.
Hawksworth, Frederick Sydney,	Wednesbury.
Howell, Edwin James,	London.
Jackson, Harold Drinkwater,	Glasgow.
Longley, Henry Banks,	Manchester.
Massey, Edward,	Warrington.
McLaren, John Alexander,	Leeds.
Meek, George Thomas,	London.
Naylor, Joe,	Halifax.
Ockenden, Maurice Albion, Jun.,	Littlehampton.
Palmer, Henry Boswell, Jun.,	Boksburg, Transvaal.
Parker, Henry Albert,	London.
Payne, Henry,	London.
Pickering, Frank,	Cape Town.
Powell, David Thomas,	London.
Purves, William Thompson,	Edinburgh.
Shaw, William Campbell,	London.
Simpson, Lightly Stapleton,	London.
Smith, John Smart, Jun.,	Aberdeen.
Statham, Harry,	Manchester.
Sutcliffe, Edgar Rouse,	Leeds.
Thomas, John Frederick Ivor,	London.
Turner, Frederick William,	Ipswich.
Turner, William,	Belfast.
Venning, Albert John, R.N.,	Mediterranean Squadron.
Williams, Charles Edward,	Sheffield.
Williams, Walter Doel,	London.

Winlaw, William Willoughby,	Newcastle-on-Tyne.
Wood, Charles,	London.
Wright, Richard Oliver,	London.
Young, Henry Wilson,	London.

GRADUATES.

Bennett, Henry Arthur Dillon,	London.
Clapham, Thomas Alborn,	Keighley.
Cooke, Stanley Walter,	London.
Down, Percy,	London.
Epps, Laurence George John,	London.
Eyers, Cyril,	Crewe.
Higgs, Arthur Franklin,	Belvedere, Kent.
Hughes, Edmund Selby,	London.
Hunton, William,	Bristol.
Josselyn, Edward,	London.
Lee, Walter,	London.
McDermott, Hugh,	London.
Miller, William Thomas Ward,	Sheffield.
Moraes, James Affleck,	Sandgate, Kent.
Morgan, David James,	Plymouth.
Rasey, Alfred Ernest,	London.
Rosevere, Reginald George,	Derby.
Smyth, Robert Henry,	Coolaney, Ireland.
Stonebridge, Arthur Watson,	Portland.
Wadham, Robert,	London.
Walton, Denys,	London.
Warner, James Sutherland,	London.
Western, Hugh,	Cairo.
Widdowson, Ernest Leedham,	Halifax.
Williams, Vernon Ingram Norbury,	Manchester.

The following Annual Report of the Council was then read:—

ANNUAL REPORT OF THE COUNCIL.

1900.

The Council have the pleasure of presenting to the Fifty-third Annual General Meeting of the Members the following Report of the progress and work of the Institution during the past year.

In February last, H.R.H. the Duke of York graciously accepted the Council's nomination as an Honorary Life Member of the Institution.

During 1899, Professor William C. Roberts-Austen, C.B., D.C.L., F.R.S., Honorary Life Member, and Mr. William H. Preece, C.B., F.R.S., have each been promoted by Her Majesty to be a Knight Commander of the Bath; and the honour of Knighthood has been conferred upon Mr. J. Fortescue Flannery, M.P.

At the end of 1899 the number of names in all classes on the roll of the Institution was 2,922, as compared with 2,684 at the end of the previous year, showing a net gain of 238. During the year there were added to the register 336 names; and the total deductions were 98, made up of 48 deceases during 1898 (see page 6, and Report of 1899), together with the 32 resignations and 18 removals announced on page 7, all of which took effect during 1899. These deductions are slightly in excess of the average. On the other hand 57 more new members were added to the Institution than during the previous year, and 112 more than in the year 1897.

Early in the year the Council took steps to call the attention of the Engineer officers of the Royal Navy to the advantages attaching to membership of the Institution. They are pleased to state that this action has resulted in many of these officers becoming members, and it is anticipated that more will join.

The following forty Deceases of Members of the Institution were reported during the year 1899:—

Bertram, Alexander,	Sheffield.
Bettig, Robert (Associate Member),	Lille.
Blake, Henry Wollaston, F.R.S.,	London.
Butter, Frederick Henry,	Woolwich.
Capel, Herbert Churchill,	London.
Carpmael, William,	London.
Charnock, James,	Moscow.
Deas, James,	Glasgow.
Devine, William Henry (Associate),	Nagasaki.
Donaldson, John,	London.
Dutch, Ernest (Associate Member),	Wigan.
Elliott, Thomas Graham,	Leeds.
Fawcett, Thomas Constantine,	Leeds.
Furness, Edward,	Gravesend.
Galton, Sir Douglas, K.C.B., D.C.L., LL.D., F.R.S.,	London.
Gaynor, Captain Henry Francis, R.E.,	Camberley.
Gibson, George Henry,	Liverpool.
Griffiths, James E.,	Cardiff.
Harvey, Charles Randolph,	Glasgow.
Haughton, S. Wilfred (deceased 1898),	Carlow.
Head, Jeremiah,	London.
Jackson, Peter Rothwell,	Manchester.
Joicey, Jacob Gowland,	Newcastle-on-Tyne.
Kershaw, Thomas (Associate Member),	Huddersfield.
Kitson, John Hawthorn,	Leeds.
Laird, William,	Birkenhead.
Martin, The Hon. James,	Gawler, S. Australia.
Maudslay, Henry,	London.
Moore, Benjamin Theophilus,	Bexley.
Naylor, John William,	Leeds.
Pattison, Giovanni,	Naples.
Phillips, Exham (Associate Member),	Manchester.
Ryland, Frederick,	West Bromwich.
Sainsbury, Francis Charles Barrett (deceased 1898),	Dublin.
Simon, Henry,	Manchester.
Smith, John,	Rochdale.
Stockwell, Charles Edward (Associate Member),	Sydney.
Wadia, The Hon. Nowrosjee Nesserwanjee, C.I.E.,	Bombay.
Wylie, John Condie,	St. Ives, Cornwall.
Young, David,	London.

Of these Sir Douglas Galton had served on the Council since 1888, having been a Vice-President for eight years; Mr. Jeremiah Head had been a Member of Council for twenty-five years, during which time he was a Vice-President for four years, and President in 1885 and 1886; Mr. William Laird had been a Member of Council for twelve years; and Mr. Peter Rothwell Jackson was an Original Member of the Institution from its establishment in 1847.

The following eighteen gentlemen have ceased to be Members of the Institution during the past year :—

Anderson, William (Graduate),	London.
Atkinson, Alexander,	Kashmir.
Berkley, James Eustace,	Bombay.
Blandford, Thomas,	Corbridge.
Byrne, Francis Furlong,	Dublin.
Frenzel, Arthur Benjamin,	New York.
Green, Henry Joseph Kersting,	Calcutta.
Holland, Calvert Bernard,	London.
Langford, William,	Birmingham.
Palchoudhuri, Bipradas (Graduate),	Krishnugher, Bengal.
Rowe, Daniel (Associate Member),	Redruth.
Sharp, Henry,	London.
Shore, Alfred Thomas,	Bombay.
Sprague, Ernest Headly,	Tientsin.
Stevinson, Thomas,	Nailsworth, Glos.
Toone, William Carson,	Warminster.
Vicars, John,	Boot, Cumberland.
Waterous, Julius E.,	Brantford, Ontario.

In addition to these, thirty-two Resignations of membership took effect on 1st January 1899.

The Accounts for the year ending 30th December 1899 are now submitted to the Members (see pages 14–17 and 22), after having been passed by the Finance Committee, and certified by Mr. Robert A. McLean, chartered accountant, the auditor appointed by the Members at the last Annual General Meeting. The Accounts have been re-arranged; and in order to give Members full information respecting the new system, the accounts for 1898 drafted in the new form are also appended (pages 18–21).

The total revenue for the year 1899 was £8,777 4*s.* 5*d.*, while the expenditure was £9,230 16*s.* 0*d.*, leaving an excess of expenditure over revenue of £453 11*s.* 7*d.* The financial position of the Institution at the end of the year is shown by the balance sheet. The total investments and other assets amount to £69,084 8*s.* 10*d.*; and, deducting therefrom the £25,000 of debentures and the total remaining liabilities £3,588 19*s.* 11*d.*, the capital of the Institution amounts to £40,495 8*s.* 11*d.* Of this sum £5,000 was set aside in 1897 and 1898 as a sinking fund for the redemption of the debentures. The sum of £6,859 4*s.* 8*d.* still remains invested in Railway Debenture Stocks and Consols, registered in the name of the Institution, of which the Union Bank of London holds the £3,945 12*s.* Midland Railway 2½ per cent. Debenture Stock, as security for a temporary loan of £3,000. A total of £59,214 0*s.* 7*d.* has now been expended upon the Institution House. The certificates of the securities have been duly audited by the Finance Committee and the auditor.

The past year is the first in which the Institution has occupied its own house, and an increase in the expenditure was inevitable. Certain expenses of a special character also had to be incurred in connection with the opening of the new house. Under these exceptional circumstances the financial result for the year has been satisfactory.

The next award of the Willans Premium devolves upon the Council at the end of the present year 1900 (see pages 22–23).

Progress has been made during the year with the various Researches undertaken by the Institution.

The Fifth Report of the Research Committee on Alloys was presented and fully discussed at the February Meeting; and Sir William C. Roberts-Austen, the Reporter, is now at work upon the Effect of Annealing and Tempering on the properties of Steel, which will form the principal subject of his next Report.

The Gas-Engine Research has been further advanced by Professor Burstall, who hopes to be able to present his Report early in the present year to the Committee, under the chairmanship of Dr. Kennedy.

The Value of the Steam-Jacket is the subject under investigation by Professor Beare, who has accumulated further data towards his Fourth Report to the Committee, of which Mr. Henry Davey is the chairman.

The Compound Steam-Jacketed Condensing Engine at King's College, London, has been working. Professor Capper has not yet been able to commence the first series of complete tests, but hopes to prepare his first Report soon.

A complete working model of a locomotive has been presented by Mr. J. A. F. Aspinall, Member of Council; and busts of Sir Mark Isambard Brunel and the late Mr. Bryan Donkin have been given by Mr. Bryan Donkin, Member of Council. The Library has also received a number of new volumes and drawings, enumerated in pages 24 to 33, from members and others. For all of these the Council here record their thanks to the several Donors. Further accessions of engineering books and pamphlets will be gratefully acknowledged.

Three two-day General Meetings have been held, those of February and April in London and that of July in Plymouth. The winter session was commenced in October by a series of Monthly Meetings. The nine days of meeting were occupied by the reading and discussion of the following Papers :—

Fifth Report to the Alloys Research Committee : Steel ; by Sir William C. Roberts-Austen, K.C.B., D.C.L., F.R.S.
Machinery for Book and General Printing ; by Mr. William Powrie.
Address by the President ; Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S.
Evaporative Condensers ; by Mr. Harry G. V. Oldham.
The South Devon Atmospheric Railway, preceded by certain remarks on the Transmission of Energy by a partially rarefied Atmosphere ; by Sir Frederick Bramwell, Bart., D.C.L., LL.D., F.R.S., Past-President.

The Launch of a Battleship; by Mr. H. R. Champness.
Railway Viaducts in Cornwall, Old and New; by Mr. T. H. Gibbons.
The Mechanical Appliances employed in the construction of the Keyham Dockyard Extension Works; by Mr. Whately Eliot.
The Machinery of H.M.S. "Proserpine" and H.M.S. "Psyche," as illustrative of the work done at Keyham, particularly with reference to the practical training of Engineer Students; by Mr. Robert Mayston, R.N.
Outlet Valves at the Burrator Reservoir of the Plymouth Water Works; by Mr. Edward Sandeman.
Refuse Disposal, and the Results obtained from six months' working of the Refuse Destructor at Torquay; by Mr. Henry A. Garrett.
The Incrustation of Pipes at Torquay Water Works; by Mr. William Ingham.
Openings for Mechanical Engineers in China; by the Right Hon. Rear-Admiral Lord Charles Beresford, C.B., M.P.
A Continuous Mean-Pressure Indicator for Steam Engines; by Professor William Ripper.

The President's Address, dealing with the connection between Mechanical Engineering and Modern Shipbuilding, was delivered at the Spring Meeting in April.

The Summer Meeting was held in Plymouth, where Papers were read by Sir Frederick Bramwell, Bart., Past-President, by the Chief Constructor and the Chief Engineer at Devonport Dockyard, and by the Admiralty Superintending Civil Engineer at the Keyham Extension Works; also by the Resident Engineer, Great Western Railway, the Water Engineer of Plymouth, and the Borough Surveyor of Torquay. All the works dealt with in these local Papers were open to the inspection of members; and other excursions were arranged to various places of interest. Mr. James Paton kindly acted as local secretary; and the members were hospitably received by the various authorities of the Three Towns, and by Sir John Jackson.

The formal opening of the new House was celebrated by a Conversazione held therein on the evenings of the 16th and 17th May. Invitations were issued to representatives of the Government, the Universities, and the Scientific Societies of the country, as well as to Members of the Institution. About 1,200 Members and Guests responded to the invitations. A brief History of the Institution was prepared for distribution on this occasion, and has been embodied in the Proceedings.

The following Table shows the attendances at the several meetings.

Attendances during 1899.

Meeting.	Feb.		April.		July.	Oct.	Nov.	Dec.
Members.	229	124	170	103	217	118	228	96
Visitors.	89	91	68	68	53	101	197	72

The Council have carefully considered the question of increasing the usefulness of the Institution to all classes of the Members and to the profession, now that the new House has been completed. It has been decided to hold monthly meetings this session, instead of quarterly meetings as heretofore, and the change has thus far proved advantageous.

Arrangements have been made also for monthly meetings of the Graduates. A Committee has been formed by the Graduates, and there is every prospect of success. A room has been set apart for their use; and a series of seven Monthly Meetings was commenced in October, when the President gave a brief Address before the reading of the first Paper. A Member of Council has presided at each of these meetings, and a good discussion has been sustained. Several excursions to places of engineering interest have also been arranged in the London district; and offers of similar facilities have been made in the provinces, which will be accepted as soon as the Graduates in each district have become organised.

The Council propose to hold the Summer Meeting of the Institution this year in London.

The result of the ballot for the election of a President, three Vice-Presidents, and five Members of Council, to fill the vacancies caused by retirement, will be announced to the meeting to-day.

ACCOUNTS FOR 1899,

FOLLOWED BY

THE ACCOUNTS FOR 1898 ARRANGED IN THE NEW FORM,

FOR COMPARISON.

Dr. ACCOUNT OF REVENUE AND EXPENDITURE

Expenditure.				£	s.	d.	£	s.	d.
To Expenses of Maintenance and Management—									
Salaries and Wages				2,285	0	0			
Postages, Telegrams, and Telephone				396	10	4			
Heating, Lighting, and Power	133	5	2						
Do., amount outstanding	20	9	7	153	14	9			
Fittings and Repairs				114	6	1			
Household and Petty Expenses	173	2	6						
Do., amount outstanding	2	10	0	175	12	6	3,125	3	8
„ Printing, Stationery, and Binding—									
Printing and Engraving Proceedings	1,653	14	10						
Do., amount outstanding	291	4	5	1,944	19	3			
Less *Authors' Copies of Papers repaid*				32	19	6			
				1,911	19	9			
Stationery and General Printing				463	8	8			
Binding				27	5	6	2,402	13	11
„ Rent, Rates, Taxes, &c.—									
Ground Rent				890	8	3			
Rates and Taxes	824	15	6						
Do., amount outstanding	14	6	6	839	2	0			
Insurance				32	14	0	1,762	4	3
„ Meeting Expenses—									
Printing				313	13	3			
Reporting				54	4	11			
Diagrams, Screen, &c.				92	16	7			
Travelling and Incidental Expenses				171	16	1	632	10	10
„ Books purchased							9	4	10
„ Research							182	4	6
„ Debenture Interest							1,000	0	0
„ Special Expenses—									
Opening Conversazione				461	2	9			
Dinner Guests				50	0	11			
Removal (balance)				5	19	0			
Interest on Bankers' Loan				32	5	1	549	7	9
							9,663	9	9
Less outstanding expenses at 1st Jan. 1899, already charged							432	13	9
							£9,230	16	0

FOR THE YEAR ENDED 30TH DECEMBER 1899. *Cr.*

Revenue.

	£	*s.*	*d.*	£	*s.*	*d.*
By Entrance Fees—						
143 *New Members at £2*	286	0	0			
145 *New Associate Members at £1*	145	0	0			
7 *New Associates*	7	0	0			
12 *Associate Members transferred to Members at £1*	12	0	0			
2 *Associates transferred to Members at £1*	2	0	0	452	0	0
„ Subscriptions for 1899—						
1846 *Members at £3*	5,538	0	0			
468 *Associate Members at £2 10s.*	1,170	0	0			
83 *Associates at £2 10s.*	207	10	0			
203 *Graduates at £1 10s.*	304	10	0			
12 *Associate Members transferred to Members at 10s.*	6	0	0			
2 *Associates transferred to Members at 10s.*	1	0	0			
1 *Graduate transferred to Associate Member at £1*	1	0	0	7,228	0	0
„ Subscriptions in arrear, paid—						
60 *Members at £3*	180	0	0			
1 *Member (instalment)*	2	17	3			
23 *Associate Members at £2 10s.*	57	10	0			
2 *Associates at £2 10s.*	5	0	0			
11 *Graduates at £1 10s.*	16	10	0	261	17	3
„ Subscriptions in advance—						
29 *Members at £3*	87	0	0			
6 *Associate Members at £2 10s.*	15	0	0			
1 *Associate at £2 10s.*	2	10	0			
4 *Graduates at £1 10s.*	6	0	0	110	10	0
„ Life Composition				40	0	0
„ Interest, &c.—						
From Bank	1	6	0			
„ *Investments*	419	7	2			
Income Tax refunded	22	12	11	443	6	1
„ Reports of Proceedings— *Extra Copies sold*				67	5	6
„ Increase in probable value of subscriptions in arrear as compared with previous year				35	0	0
„ Profit on Sale of India Stock	353	3	9			
Less Loss on Sale of Consols	213	18	2	139	5	7
				8,777	4	5
„ Balance, being excess of Expenditure over Revenue, carried to Balance Sheet				453	11	7
				£9,230	16	0

Dr. BALANCE SHEET

	£	s.	d.	£	s.	d.	£	s.	d.
To Debentures—									
250 *of* £100 *each at* 4%, *redeemable in* 1917, *or at par at any date after* 1st *Jan.* 1908, *on six months' notice to holder*							25,000	0	0
,, Cash—									
Union Bank of London, overdraft				482	9	8			
Less *In London Joint Stock Bank*	276	9	1						
,, *Hand*	19	12	7	296	1	8	186	8	0
,, Sundry Creditors—									
Loan from Union Bank of London				3,000	0	0			
Accounts owing, not yet rendered				328	10	6			
Willans Premium Fund				9	10	8			
Unclaimed Debenture Interest				64	10	9	3,402	11	11
,, Capital of the Institution :—									
(1) *Balance at* 31 *December* 1898	35,949	0	6						
Less *Excess of Expenditure over Revenue for the year ended* 30 *December* 1899	453	11	7	35,495	8	11			
(2) *Set aside in* 1897 *and* 1898 *as a Sinking Fund for redemption of Debentures*				5,000	0	0	40,495	8	11
							£69,084	8	10

Signed by the following members of the Finance Committee :—

WILLIAM H. MAW,
BRYAN DONKIN,
JOHN G. MAIR-RUMLEY.

AT 30TH DECEMBER 1899. *Cr.*

	£	s.	d.
By Investments . . . . (*at cost*)	6,859	4	8
£ 4,237 *London and North Western Ry.* 3% *Debenture Stock* 3,945 12*s. Midland Railway* * 2½% " " 1,000 *Consols* 2¾% *The Market Value of these investments at* 30*th Dec.* 1899 *was about* £8,856, *of which* £5,000 *is reserved for Sinking Fund.*			
" Subscriptions in Arrear, *probable value*	291	0	0
" Furniture and Fittings	1,315	12	10
" Drawings, Engravings, Models, Specimens, and Sculpture .	100	0	0
" Library	1,240	0	0
" Amount in Union Bank to meet unclaimed Debenture Interest	64	10	9
" Proceedings, back numbers, *cost* £5,290			
" Institution House, expenditure to date	59,214	0	7
	£69,084	8	10

* See page 8.

Audited and Certified by

ROBERT A. McLEAN, F.C.A.,
Auditor,
1 Queen Victoria Street, London, E.C.

Accounts for 1898 printed in for comparison with those for 1899

Dr. ACCOUNT OF REVENUE AND EXPENDITURE

Expenditure.

	£	s.	d.	£	s.	d.
To Expenses of Maintenance and Management—						
Salaries and Wages	2,063	17	6			
Postages, Telegrams, and Telephone	328	12	1			
Heating, Lighting, and Power	50	7	1			
Fittings and Repairs	27	6	11			
Travelling Expenses	3	13	4			
Household and Petty Expenses	51	16	9	2,525	13	8
,, Printing, Stationery, and Binding—						
Editing, Printing, and Engraving Proceedings	2,040	17	10			
Reprinting former Proceedings	21	4	0			
	2,062	1	10			
Less Authors' Copies of Papers, repaid	5	11	6			
	2,056	10	4			
Stationery and General Printing	257	6	1			
Binding	28	14	4	2,342	10	9
,, Rent, &c.—						
Rent of Offices (19 *Victoria Street*)	710	0	0			
Insurance	42	7	9	752	7	9
,, Meeting Expenses—						
Printing	286	17	9			
Reporting	51	14	0			
Diagrams, Screen, &c.	111	14	1			
Travelling and Incidental Expenses	172	5	10	622	11	8
,, Books purchased				27	7	4
,, Research				217	8	10
,, Debenture Interest				1,000	0	1
Special Expenses—						
Honorarium to retiring Secretary	3,000	0	0			
Dinner Guests	56	4	10			
Removal (part)	44	8	0			
Written off value of Investments, owing to resolution of Finance Committee to take cost price of Investments instead of market price, and to loss on sale of Investments	3,847	2	8			
Decrease in probable value of subscriptions in arrear as compared with 31st December 1897	9	0	0	6,956	15	6
,, Sinking Fund—						
Amount set aside this year				2,500	0	0
				£16,944	15	7

the new form
(see pages 14–15).

FOR THE YEAR ENDED 31ST DECEMBER, 1898. *Cr.*

Revenue.

	£	s.	d.	£	s.	d.
By Entrance Fees—						
124 *New Members at £2*	248	0	0			
103 *New Associate Members at £1*	103	0	0			
13 *New Associates at £1*	13	0	0			
14 *Associate Members transferred to Members at £1*	14	0	0			
2 *Associates transferred to Members at £1*	2	0	0			
1 *Graduate transferred to Member at £1*	1	0	0	381	0	0
,, Subscriptions for 1898—						
1,747 *Members at £3*	5,241	0	0			
361 *Associate Members at £2 10s.*	902	10	0			
81 *Associates at £2 10s.*	202	10	0			
184 *Graduates at £1 10s.*	276	0	0			
14 *Associate Members transferred to Members at 10s.*	7	0	0			
2 *Associates transferred to Members at 10s.*	1	0	0			
1 *Graduate transferred to Member at £1 10s.*	1	10	0			
4 *Graduates transferred to Associate Members at £1*	4	0	0	6,635	10	0
,, Subscriptions in arrear—						
70 *Members at £3*	210	0	0			
12 *Associate Members at £2 10s.*	30	0	0			
2 *Associates at £2 10s.*	5	0	0			
2 *Graduates at £2*	4	0	0			
16 *Graduates at £1 10s.*	24	0	0	273	0	0
,, Subscriptions in advance—						
25 *Members at £3*	75	0	0			
1 *Associate Member at £2 10s.*	2	10	0			
2 *Associates at £2 10s.*	5	0	0			
3 *Graduates at £1 10s.*	4	10	0			
	87	0	0			
Less 1 *Graduate at £1 10s., refunded*	1	10	0	85	10	0
,, Life Compositions				212	0	0
,, Interest—						
From Investments	743	7	0			
From Bank	17	10	7			
Income Tax refunded (3 years)	75	15	6	836	13	1
,, Reports of Proceedings— *Extra copies sold*				73	4	8
,, Reserve in previous year against accounts owing	600	0	0			
Less general accounts owing, not yet rendered	432	13	9	167	6	3
,, Balance carried to Capital Account— *Excess of Expenditure over Revenue for the year ended 31st December 1898*				8,280	11	7
				£16,944	15	7

Accounts for 1898 printed in for comparison with those for 1899

Dr. BALANCE SHEET

	£ s. d.	£ s. d.	£ s. d.
To Debentures—			
250 *of* £100 *each at* 4%, *redeemable in* 1917, *or at par at any date after* 1st *January* 1908, *on six months' notice to holder*			25,000 0 0
„ Sundry Creditors—			
Accounts owing, not yet rendered, say . . .		432 13 9	
Unclaimed Debenture Interest		81 4 1	513 17 10
„ Capital of the Institution—			
(1) *Balance at* 31 *December* 1897	44,229 12 1		
Less *Excess of Expenditure over Revenue for year ended* 31 *December* 1898	8,280 11 7	35,949 0 6	
(2) *Set aside in* 1897 *and* 1898 *as a Sinking Fund for redemption of Debentures* . .		5,000 0 0	40,949 0 6
			£66,462 18 4

the new form
(see pages 16–17).

AT 31ST DECEMBER 1898. *Cr.*

				£	s.	d.	£	s.	d.
By Cash—									
In Union Bank, on Current Account				995	1	5			
" " " *unclaimed Debenture Interest*				81	4	1			
	£	s.	d.						
" *London Joint Stock Bank* . .	342	11	7						
Cash Balance at 3rd December 1898 (*when expenditure account closed*) *since spent*	157	8	5	500	0	0	1,576	5	6
" Investments . . . . *cost*							15,403	4	4
£									
4,237 *London and North Western Ry.* 3% *Debenture Stock*									
3,945 12*s*. *Midland Railway* 2½% " "									
4,053 *India* 3% *Stock*									
5,000 *Consols* 2¾%									
The Market Value of these investments at 31*st December* 1898 *was about* £18,281, *of which amount* £5,000 *is reserved for Sinking Fund.*									
" Subscriptions in arrear, *probable value*							256	0	0
" Office Furniture and Fittings							343	0	0
" Drawings, Engravings, Models, Specimens, and Sculpture .							100	0	0
" Library							1,240	0	0
" Proceedings, back numbers, *cost* £5,200									
" Institution House, expenditure to date							47,544	8	6
							£66,462	18	4

WILLANS PREMIUM FUND.

Investment £159 8*s*. 5*d*. of India 3% Stock	cost	£165 5*s*. 0*d*.

Dr.	£ *s*. *d*.	*Cr.*	£ *s*. *d*.
To Balance, held in trust .	9 10 8	By Interest, 1898 . .	4 15 4
		„ „ 1899 . .	4 15 4
	£9 10 8		£9 10 8

Audited, certified, and signed by the names on pages 16–17.

DECLARATION OF TRUST
OF THE WILLANS PREMIUM FUND.

To all to whom these presents shall come The Institution of Mechanical Engineers and The Institution of Electrical Engineers send greeting. Whereas a Fund has been subscribed by the friends of the late PETER WILLIAM WILLANS, of Thames Ditton, for the purpose of commemorating his name and the services which he rendered to Engineering and Electrical science; and at the request of the subscribers to the said fund the above-named Institutions have agreed to act as joint Trustees thereof, and the sum of One hundred and sixty-five pounds has accordingly been paid to the said Institutions: now these presents witness that the said Institutions do hereby declare the Trusts upon which they hold the said fund to be as follows:—

1. To invest the said fund upon such securities as trustees are by law authorised to hold, and in such names as the Councils of the two Institutions shall from time to time direct.

2. To apply the proceeds of the said investment as and when received, after payment of any expenses incidental to the

administration of the trust, to the Premium hereinafter described, to be known as "the Willans Premium."

3. The Willans Premium shall be awarded alternately by the Council of each of the above-mentioned Institutions; and first by The Institution of Electrical Engineers in December 1897.

4. The Council of the awarding Institution in each alternate period shall award the Willans Premium for the best original paper communicated to their Institution, dealing with such a general subject as the utilisation or transformation of energy, treated especially from the point of view of efficiency or economy: provided that the Premium shall not be awarded unless a paper of sufficient merit in the judgment of the awarding Council shall have been so communicated since the preceding award of that Council.

5. The Premium shall be awarded triennially in and after December 1897, unless otherwise determined by resolution of the respective Councils of the two Institutions.

6. The Premium may be awarded either in money or books or medal, or in any other form which in the instance of any individual award the awarding Council may then determine.

7. In case of no award at the end of any triennial period, the premium available for that award shall be added to the capital of the fund.

In witness whereof The Institution of Mechanical Engineers have hereunto affixed their common seal, and the President and Secretary of The Institution of Electrical Engineers have hereunto set their hands, this sixteenth day of January 1895.

The Seal of The Institution of Mechanical Engineers was impressed by the President in the presence of Alfred Bache, Secretary; and the document was signed as follows:—

ALEXANDER B. W. KENNEDY,
President of The Institution of Mechanical Engineers.
R. E. CROMPTON,
President of The Institution of Electrical Engineers.
F. H. Webb, Secretary of The Institution of Electrical Engineers.

LIST OF DONATIONS TO THE LIBRARY.

Books.

Cycles of Gas and Oil Engines, by J. D. Roots; from the author.

Compte Rendu des Fêtes du Cinquantenaire de la Société des Ingénieurs Civils de France; from Monsieur Alfred Loreau.

Diagrams for the Graphic Calculation of Earthwork Quantities, by A. H. Roberts; from the author.

Streets and Traffic of London, by Sir J. Wolfe Barry, K.C.B., LL.D., F.R.S.; from the author.

Commercial Management of Engineering Works, by F. G. Burton; from Mr. W. H. Fowler.

Testing of Materials of Construction, by Prof. W. Cawthorne Unwin, F.R.S.; from the author.

Modern Labour, by J. S. Ransome; Modern Wood-working Machinery, by J. S. Ransome; from the author.

Henry Bessemer, 1813–1898, by James Dredge, C.M.G.; from the author.

Notes on Water Supply, by J. T. Rodda; from the author.

Hydraulic Mining: Part I, Ditches, and Part II, Flumes, Tunnels, Pipes, by Capt. C. C. Longridge; from the author.

Supplement to Lord Armstrong's Work on Electric Movement in Air and Water; from the Rt. Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S.

Steam Locomotion on Common Roads, by William Fletcher; from the author.

Commercial and Business Aspects of Municipal Electricity Supply, by A. H. Gibbings; from the author.

Mechanics Applied to Engineering, by Prof. John Goodman; from the author.

First Principles of Mechanical and Engineering Drawing, by H. Holt-Butterfill; from the author.

Handbook of Saw-mill and Wood-converting Machinery, by M. Powis Bale; Modern Shafting and Gearing and the economical transmission of power, by M. Powis Bale; from the author.

Metal-Plate Work, its patterns and their geometry, by C. T. Millis; from the author.

Tables and Data for the use of Students in Engineering Laboratories, by Prof. W. W. F. Pullen; from the author.

Notes on the Steam Engine, by Prof. H. J. Spooner; Practical Plane and Solid Geometry, by Prof. H. J. Spooner; from the author.

Elements of Machine Construction and Drawing, by Prof. H. J. Spooner and E. G. Davey; from Prof. H. J. Spooner.

Elementary Treatise on Practical Mathematics, by John Graham; from the publisher.

Treatise on Surveying, by R. E. Middleton and Osbert Chadwick, C.M.G.; from Mr. R. E. Middleton.

Steam-Engine Theory and Practice, by Prof. William Ripper; from the publishers.

Central Station Electricity Supply, by Albert Gay and C. H. Yeaman; from the publishers.

Strength of Materials, by Prof. J. A. Ewing, F.R.S.; from the Syndics of Cambridge University Press.

Report on the Concessions of the Pekin Syndicate in the Provinces of Shansi and Honan, China, with Estimates of Cost of Railways and other Works necessary for their development, by J. G. H. Glass, C.I.E.; from the Syndicate.

The following books and pamphlets from Mr. Henry Chapman:—Official Descriptive and Illustrated Catalogue of the Great Exhibition of 1851; Official Illustrated Catalogue of the International Exhibition, London, 1862; International Exhibition, 1862, Medals and Honourable Mentions awarded by the International Juries, with a List of Jurors and the Report of the Council of Chairmen; Exhibited Machinery of 1862, by D. K. Clark; Paris Universal Exhibition, 1867, Complete Official Catalogue, English version; Paris Universal Exhibition, 1867, Catalogue of the British Section; Description of the Machines à l'Exposition de Vienne, 1873; Mémoire sur l'Exposition de Vienne, by H. Fontaine; British Section at the Vienna Universal Exhibition, 1873, Official Catalogue; Paris Universal Exhibition, 1878, Catalogue of the British Section; Exposition Universelle Internationale de 1878, Paris, Catalogue Officiel, Liste des Récompenses; Exposition Universelle Internationale de 1878, Paris, Rapports sur la Matériel des Chemins de fer, by F. Jacqmin; Exposition Universelle Internationale de 1878, Paris, Catalogue Officiel; Métallurgie du Fer à l'Exposition Universelle de 1878, by P. Duteil; Exposition Internationale d'Électricité, Paris, 1881, Catalogue Général Officiel; International Inventions Exhibition, London, 1885 (Preliminary Pamphlet); International Inventions Exhibition, 1885, Official Catalogue; Paris Universal Exhibition, 1889, Official Catalogue of the British Section; Exposition Universelle Internationale de 1889, Paris, Catalogue Général Officiel; Quatrième Congrès International de Navigation Intérieure, tenu à Manchester en 1890, Canal Maritime de Manchester, by De Pulligny; Brussels International Exhibition, 1897, Catalogue of British Section; First and Second Reports of the Royal Commissioners on Technical Instruction; Sanitary Registration of Buildings Bill, 1887, by R. E. Middleton; Essai entrepris par la Compagnie de l'Est pour le Chauffage des trains au moyen de la vapeur et de l'air comprimé combinés, by F. Lancrenon; Personal Recollections of English Engineers, by a Civil Engineer; Autobiography of Sir John Rennie, F.R.S.; James Nasmyth, Engineer, an Autobiography, by S. Smiles; Life of Joseph Locke, by J. Devey; Lives of Boulton and Watt, by S. Smiles; Memoir of the Life of Sir M. I. Brunel, by R. Beamish; Tableau Généalogique Famille Brunel d'Hagueville; Étude sur les Locomotives, by E. Furno; Étude sur les Locomotives Anglaises, by M. Demoulin; Industrial Biography: Iron Workers and Tool Makers, by S. Smiles; War-ships of Europe, by Chief Engineer King, U.S.N.; Men of Invention and Industry, by S. Smiles.

The following official publications from the Government of New South Wales:—Annual Report of the Railway Commissioners for the year ending 30 June 1899; Report of the Department of Public Works for the year ended 30 June 1898; Annual Report of the Department of Mines and Agriculture, 1897; Tenth Report of the Metropolitan Board of Water Supply and Sewerage, 1897–98; Seven Colonies of Australasia, 1897–98, by T. A. Coghlan.

The following official publications from the Government of New Zealand:—New Zealand Mines Record, Vols. 1 and 2, and Nos. 1 and 2 of Vol. 3; Papers and Reports relating to Minerals and Mining, 1896–98; Statistics of the Colony of New Zealand, 1896–98; Public Works Statement, 1896–99; Railway Statement, 1897–99; Official Year Book, 1896, 1898, and 1899.

Guide to Queensland, by C. S. Rutlidge; from the Queensland Government.

Reports of the Inspection of Mines in India, 1897 and 1898, by James Grundy; from the India Office.

The following from the U.S. Geological Survey:—Eighteenth Annual Report, Parts I, II, III, IV and V (2 vols), 1896–97; Nineteenth Annual Report, Parts I, IV, VI and VI continued, 1897–98; Monographs, XXIX, XXXI (with Atlas), and XXXV.

The following from the Ordnance Office, U.S. America:—Tests of Metals, &c., at Watertown Arsenal, Massachusetts, 1897 and 1898; Notes on the Construction of Ordnance.

The following from California University, U.S. America:—California University Chronicle, Vol. I, Nos. 1–6; Biennial Report of the President, 1896–98; Annual Reports of the Secretary, 1897 and 1898; Partial Report of Work of the Agricultural Experiment Stations, 1895–96 and 1896–97; Register, 1897–98; Beitrage zur Kometenbahnbestimmung, by A. O. Leuschner.

Pamphlets.

Seven Years in a Black Country Town (with supplement), by C. L. N. Wilson; from the author.

Working of Steam Boilers, by E. G. Hiller; from the National Boiler and General Insurance Co.

The World's Exchanges in 1898, by J. H. Norman; from the author.

Trials of Motor vehicles for heavy traffic, Liverpool, 1898; from the Self-propelled Traffic Association.

Report of the Hydraulic Engineer on the Water Supply of Queensland, 1898; from Mr. J. B. Henderson.

Presidential Address, American Society of Mechanical Engineers, 1898, by C. W. Hunt; from the author.

Chilled Rolls, and why they break, by E. D. Nicholson; from the South Staffordshire Institute of Iron and Steel Works' Managers.

The Steam Tricycle of 1881, by A. H. Bateman; from the author.

La Nouvelle Science Géométrique, Géométrie du cercle, by J. F. Igúrbide; from the publishers.

Annnal Reports of the Chief of the Bureau of Steam Engineering, U. S. America, 1898 and 1899; from the Engineer-in-Chief.

Distribution of Electrical Energy, by C. H. Wordingham; Lectures on the Production and Distribution of Electrical Energy, by C. H. Wordingham; from the author.

Manchester Corporation Electric Works: particulars of generating and distributing plant; from Mr. C. H. Wordingham.

Development of Modern Industry, by Henry Webb; from the author.

Application de la Surchauffe aux Machines à Vapeur, by F. Sinigaglia; from the author.

Manufacturing Costs Accounts, their use and treatment, by Ernest Andrade; from the author.

Report of the Special Committee on Secret Commissions: with Appendices; from the London Chamber of Commerce.

Account of the Breakwater in Plymouth Sound, by Sir John Rennie, F.R.S.; from Mr. George B. Rennie.

Annual Reports relating to the Public Works Department of the Stadsraad, Johannesburg, S. A. R., 1897 and 1898; from Mr. Charles Aburrow.

Desert Railway, by J. Grant Birch; from Mr. H. C. Matheson.

The Institute of Chartered Accountants in England and Wales; from Mr. James Forrest.

The Slide Rule, by C. N. Pickworth; from the author.

Report of the Kew Observatory Committee, 1898; Experiments on Aneroid Barometers at Kew Observatory, and their Discussion, by C. Chree, LL.D., F.R.S.; from the Committee.

Weak Points in Naval Administration, by Charles M. Johnson, R.N.; from the author.

Fourth Annual Report 1898 of the John Crerar Library, Chicago; from the Library.

Progrès récents des Installations de Laminage; from Monsieur S. Jordan.

Quick Revolution Steam-Engines, by Arthur Herschmann; from the author.

Historical Sketch of the first Institution of Mining Engineers, by Bennett H. Brough; from the author.

List of Chinese Lighthouses, Light-vessels, Buoys and Beacons, 1899; from the Inspector-General of Chinese Customs.

Petroleum Industry of Roumania, by D. A. Sutherland; from the author.

Map of the Canals of England and Wales; from Mr. Lionel B. Wells.

Report on the Uganda Railway, by Sir Guilford Molesworth, K.C.I.E.; from the author.

Laws of Japan, Copyright, &c.; from Mr. W. Silver Hall.

Locomotives à Tiroirs Cylindriques, système Ricour, by P. Guédon; from the author.

Water Gas—what is it, how is it made? by A. O. Granger; Analysis Report on the Granger Water Gas, by Dr. G. E. Moore; from Mr. A. O. Granger.

Fitting of the Cycle to its rider, by R. E. and C. Crompton; from Mr. C. O. Grimshaw.

Lake Superior Iron-ore Mines and their influence upon the production of Iron and Steel, by Jeremiah and A. P. Head; from Mr. A. P. Head.

Report upon the Manufacture of Iron and Steel in India, by Major R. H. Mahon, R.A.; from the author.

Destruction of Towns Refuse with special reference to the Econometer, by R. B. Hodgson; from the author.

Natural and Artificial Methods of Ventilation; from the publishers.

Presidential Address to the Mechanical Science Section, British Association, 1899, by Sir William H White, K.C.B., LL.D., D.Sc., F.R.S.; from the author.

Giessereibetrieb am Ende des neunzehnten Jahrhunderts, by A. Ledebur; from the author.

Engineering Arithmetic and Mensuration, by Charles R. Honiball; from the author.

Notes on the Water Supply of the South of England, with sections, by Edward Margrett; from the author.

Description of Pumping-Engines at the Hatton pumping-station of the Staffordshire Potteries Waterworks Company, by F. Milnes Favell; from the author.

Some unrecognized Functions of our State Universities, by Prof. J. B. Johnson; from the author.

La Carbolite, nuovo carburo attenuto dalle loppe d'alto forno; L'Industria del Cemento negli Stati Uniti; I vantaggi caratteristici delle Caldaie a Vapore a Tubi d'Acqua; from Signor A. Pacchioni.

Rede zum Geburtsfeste Seiner Majestät des Kaisers und Königs Wilhelm II in der Aula der Königlichen Technischen Hochschule zu Berlin, 26 Januar 1899; Reine Mathematik in den jahren 1884–99, nebst Actenstücken zum leben von S. Aronhold, by Dr. E. Lampe; Chronik der Königlichen Technischen Hochschule zu Berlin, 1799–1899; Rede zum Antritt des Rektorates der Königlichen Technischen Hochschule zu Berlin, 1 July 1899, by A. Riedler; from the Rector.

Register of the Institute of Chemistry of Great Britain and Ireland, 1899–1900; from the Institute.

Sixteenth and Seventeenth Reports of the Working of the Boiler Explosions Acts, during the years ending 30 June 1898 and 1899; Board of Trade Reports on Boiler Explosions; from the Board of Trade.

Classified Lists and Distribution Returns of Establishment, Indian Public Works Department, to 31 December 1898 and 30 June 1899; from the Registrar.

Yorkshire College, Leeds, Annual Report, 1897–98; from the College.

Report to the Governors of the City and Guilds of London Institute, March 1899; from the Institute.

Catalogue of the Michigan College of Mines, 1896–98; from the College.

Purdue University, Annual Catalogue, 1898–99; from Prof. W. F. M. Goss.

Calendars 1899–1900 from the following Colleges:—Royal Technical High School, Berlin; Mason University College, Birmingham; University College, Bristol; Technical College, Coatbridge; University College, Dundee; Glasgow and West of Scotland Technical College; King's College, London; City of London College; Royal Technical High School, Munich (Calendar and Report); Redruth School of Mines, Cornwall; University College, Sheffield; Civil Engineering College, Sibpur.

Lockwood's Builder's, Architect's, Contractor's and Engineer's Price Book, 1899; from the publishers.

The Advertiser's A. B. C., 1899; from the publishers.

Molesworth's Pocket-book of Engineering Formulæ; from the publishers.

Universal Directory of Railway Officials, 1899; from the publishers.

Fowler's Mechanical Engineers' Pocket-book, 1900; from the author.

Engineering and Electric Traction Pocket-book, by Philip Dawson; from the publishers.

The following Abridgments of Specifications of Patents for Inventions, 1889–92:—9, 20, 55, 78, 82, 83, 106, 125; 1893–96:—1–43, 45–51, 53–57, 59–68, 70–77, 85, 86, 89, 90, 92, 93, 98, 103, 120, 132, 136, 142, 144; from the Patent Office.

Drawings and Photographs.

Original Drawings (24) of Historical Locomotives; from Mr. David Joy.

Photographs (13) of Locomotives built by the Avonside Engine Co., Bristol; from Mr. Robert Blake.

Photographs (6) of Kimberley Mines; from Mr. Edward Comerford.

Photographs (2) of Train blown over on South Indian Railway; from Mr. G. S. Bruce.

Photograph of Ten-wheeled Express Passenger Engine, Lancashire and Yorkshire Railway; from Mr. John A. F. Aspinall.

Illustrated Catalogues.

Mining Machinery, &c., and Air Compressors; from the Ingersoll Sergeant Drill Co.

Machine Tools; from Mr. W. S. Accles.

Baldwin Locomotive Works, Records of recent construction, 1899; from the company.

Conveyors, &c.; from the New Conveyor Co.

Water-tube Marine Boilers; from the Babcock and Wilcox Co.

Imperial Positive Water Meter; from Messrs. Beck and Co.

Tires and Steel-tired Wheels; from the Standard Steel Works Co.

Machine Tools, &c.; from Messrs. William Sellers and Co.

Boiler Fittings; from Messrs. J. Hopkinson and Co.

The following Publications from the respective Societies and Authorities:—

Reports of the Academy of Science, France.

Annales des Ponts et Chaussées, Paris.

Proceedings of the French Institution of Civil Engineers.

Journal of the French Society for the Encouragement of National Industry.

Annales des Mines.

Annales du Conservatoire des Arts et Métiers.

Journal of the Marseilles Scientific and Industrial Society.

Proceedings of the Industrial Society of St. Quentin et de l'Aisne.

Proceedings of the Industrial Society of the North of France.

Proceedings of the Industrial Society of Rouen.

Proceedings of the Industrial Society of Mulhouse.

Bulletins of the French Technical Maritime Association.

Annals of the Association of Engineers of Ghent.

Proceedings of the Society of German Engineers.

Reports of the Royal Academy of Science, Belgium.

Reports of the Royal Institute of Engineers, Holland.

Bulletins of the International Railway Congress.
Proceedings of the Engineers' and Architects' Society of Canton Vaud.
Proceedings of the Engineers' and Architects' Society of Austria.
Proceedings of the Engineers' and Architects' Society of Prague.
Technicky Obzor, Prague.
Proceedings of the Architects' and Engineers' Society of Hannover.
Proceedings of the Italian Engineers' and Architects' Society.
Proceedings of the Swedish Technical Society.
Teknisk Ugeblad, Christiania.
Journal of the Franklin Institute.
Transactions of the American Society of Civil Engineers.
Transactions of the American Society of Mechanical Engineers.
Transactions and Proceedings of the American Philosophical Society.
Journal of the Western Society of Engineers, Chicago.
Proceedings of the American Institute of Mining Engineers.
School of Mines Quarterly, Columbia College, New York.
Reports of the Smithsonian Institution.
Report of the Master Car-Builders' Association, New York.
Proceedings of the United States Naval Institute.
United States Patent Office Gazette.
Journal of the Association of Engineering Societies.
Journal of the United States Artillery.
Transactions of the Canadian Society of Civil Engineers.
Proceedings and Journal of the Asiatic Society of Bengal.
Journal of the Japan Society of Mechanical Engineers.
Proceedings of the South African Association of Engineers and Architects.
Proceedings and Transactions of the Nova Scotian Institute of Science.
Proceedings of the Engineering Association of New South Wales.
Journal and Proceedings of the Royal Society of New South Wales.
Proceedings of the Institution of Civil Engineers.
Journal of the Iron and Steel Institute.
Transactions of the Society of Engineers.
Journal of the Institution of Electrical Engineers.
Transactions of the Chartered Institute of Patent Agents.
Transactions of the North of England Institute of Mining and Mechanical Engineers.
Proceedings of the South Wales Institute of Engineers.
Transactions of the Institution of Engineers and Shipbuilders in Scotland.
Transactions of the Chesterfield and Midland Counties Institution of Engineers.
Transactions of the Liverpool Engineering Society.
Transactions of the Midland Institute of Mining, Civil, and Mechanical Engineers.
Proceedings of the Cleveland Institution of Engineers.

Transactions of the Mining Institute of Scotland.
Transactions of the North-East Coast Institution of Engineers and Shipbuilders.
Proceedings of the South Staffordshire Institute of Iron and Steel Works' Managers.
Philosophical Transactions and Proceedings of the Royal Society of London.
Proceedings of the Royal Institution of Great Britain.
Transactions and Professional Notes of the Surveyors' Institution.
Journal of the Royal United Service Institution.
Professional Papers of the Royal Engineers' Institute.
Journal of the Royal Agricultural Society of England.
Transactions of the British Association of Waterworks Engineers.
Report of the Royal Cornwall Polytechnic Society.
Transactions of the Institution of Naval Architects.
Transactions and Journal of the Royal Institute of British Architects.
Transactions of the Incorporated Gas Institute.
Proceedings of the Physical Society of London.
Science Abstracts—Physics and Electrical Engineering.
Proceedings of the Literary and Philosophical Society of Manchester.
Transactions of the Manchester Geological Society.
Journal of the Royal Scottish Society of Arts.
Proceedings of the Philosophical Society of Glasgow.
Transactions and Proceedings of the Royal Irish Academy.
Transactions and Proceedings of the Royal Dublin Society.
Transactions of the Institute of Marine Engineers.
Journal of the Society of Arts.
Journal of the Society of Chemical Industry.
Transactions of the Manchester Association of Engineers.
Transactions of the Institution of Junior Engineers.
Journal of the West of Scotland Iron and Steel Institute.
Publications of the British Fire Prevention Committee.
Reports of the Manchester Steam Users' Association; from the Association.
Report of the Engine, Boiler, and Employers' Liability Insurance Company; from Mr. Michael Longridge.
Report to the Council of the Neapolitan Steam Boiler Association, by Francesco Sinigaglia; from the Association.
Forty-sixth Annual Report of the Liverpool Free Public Library.
Forty-seventh Annual Report of the Manchester Public Free Libraries.
Catalogue of Additions during 1898 to the Radcliffe Library, Oxford.
Twenty-eighth Annual Report of the Derby Free Library.

The following Periodicals from the respective Editors :—

American Machinist.
Arms and Explosives.
The Autocar.
The British Architect.
The Builder.
Camera Club Journal.
Cassier's Magazine.
Cold Storage and Ice Trades Review.
The Colliery Guardian.
The Contract Journal.
The Cyclist.
Domestic Engineering.
The Electrical Engineer.
The Electrical Review.
The Electrician.
The Engineer.
The Engineer and Iron Trades' Advertiser.
Engineering.
The Engineering Magazine.
The Engineering and Mining Journal.
The Engineering Record.
Engineers' Gazette.
Feilden's Magazine.
The Fireman.
The Journal of Gas Lighting.
Giornale del Genio Civile.
Glaser's Annalen.
Heating and Ventilation.
The Indian and Eastern Engineer.
L'Industrie.
Industries and Iron.
El Ingeniero Español.
Invention.
Inventor's Review.
The Iron and Coal Trades Review.
Iron Trade Circular, Ryland's.
The Ironmonger.
Ironmongery.
Lightning.
London Technical Education Gazette.
The Machinery Market.
The Marine Engineer.
Marine Review.
The Mariner.
The Mechanical Engineer.
The Mechanical World.
The Mining Journal.
Phillips' Monthly Machinery Register.
The Plumber and Decorator.
The Practical Engineer.
Property Gazetteer.
The Public Health Engineer.
The Railway Engineer.
Railway Master Mechanic.
The Railway Review.
Revue générale des Chemins de fer
Revue universelle des Mines.
The Shipping World.
Specification.
Stahl und Eisen.
The Steamship.
Street Railway Journal.
Tenders and Contracts.
The Textile Recorder.
Transport.
Water.

The CHAIRMAN, in moving the adoption of the Report, said he thought it spoke for itself. The Council had worked very hard to get the House in order and to increase the number of members. The work of the Research Committees had not been neglected, and he believed that this work was some of the most valuable that was being done. He hoped the Institution would continue to prosper as it had done in the past, that its work would prove exceedingly useful, and that a large number of students would avail themselves of the Graduates' Evenings. He would be glad to hear any remarks that any member might wish to make on the subject of the Report, or to give any explanation that might be required. The expenditure had increased, and had exceeded the income, but, considering how much had been done during the first year in the new building, it was not a thing to be wondered at.

Mr. EDWARD P. MARTIN, Vice-President, seconded the motion.

No further remarks being offered, the Report was unanimously adopted.

The CHAIRMAN announced that the Ballot Lists for the election of Officers for the present year had been opened by a committee of the Council, and that the following were found to be elected:—

PRESIDENT.

SIR WILLIAM H. WHITE, K.C.B., LL.D., D.Sc., F.R.S.,	London.

VICE-PRESIDENTS.

JOHN A. F. ASPINALL,	Manchester.
EDWARD P. MARTIN,	Dowlais.
J. HARTLEY WICKSTEED,	Leeds.

MEMBERS OF COUNCIL.

HENRY CHAPMAN,	London.
HENRY A. IVATT,	Doncaster.
HENRY D. MARSHALL,	Gainsborough.
SAMUEL R. PLATT,	Oldham.
JOHN I. THORNYCROFT, F.R.S.,	London.

The Council for the present year is therefore as follows:—

PRESIDENT.

Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S.,	London.

PAST-PRESIDENTS.

The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S.,	Newcastle-on-Tyne.
Sir Lowthian Bell, Bart., F.R.S.,	Northallerton.
Sir Frederick J. Bramwell, Bart., D.C.L., LL.D., F.R.S.,	London.
Sir Edward H. Carbutt, Bart.,	London.
Samuel Waite Johnson,	Derby.
Alexander B. W. Kennedy, LL.D., F.R.S.,	London.
E. Windsor Richards,	Caerleon.
John Robinson,	Leek.
Percy G. B. Westmacott,	Ascot.

VICE-PRESIDENTS.

John A. F. Aspinall,	Manchester.
Arthur Keen,	Birmingham.
Edward P. Martin,	Dowlais.
William H. Maw,	London.
T. Hurry Riches,	Cardiff.
J. Hartley Wicksteed,	Leeds.

MEMBERS OF COUNCIL.*

Sir William Arrol, M.P., LL.D.,	Glasgow.
Sir Benjamin Baker, K.C.M.G., LL.D., F.R.S.,	London.
Henry Chapman,	London.

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* Owing to the election of Mr. Aspinall as a Vice-President, a vacancy has occurred among the Members of Council. An appointment to fill this vacancy for the present year may be made by the Council at their next Meeting.

HENRY DAVEY,	London.
WILLIAM DEAN,	Swindon.
BRYAN DONKIN,	London.
EDWARD B. ELLINGTON,	London.
H. GRAHAM HARRIS,	London.
HENRY A. IVATT,	Doncaster.
HENRY D. MARSHALL,	Gainsborough.
THE RIGHT HON. WILLIAM J. PIRRIE, LL.D.,	Belfast.
SAMUEL R. PLATT,	Oldham.
SIR THOMAS RICHARDSON, M.P.,	Hartlepool.
JOHN I. THORNYCROFT, F.R.S.,	London.

The CHAIRMAN reminded the Members that at the present meeting the appointment had to be made of an Auditor for the current year.

Mr. JAMES WRIGHT moved:—"That Mr. Robert A. McLean, F.C.A., chartered accountant, 1 Queen Victoria Street, London, be re-appointed to audit the accounts of the Institution for the present year at the same remuneration as last year, namely Twenty-five Guineas."

Mr. WILLIAM SCHÖNHEYDER seconded the motion, which was carried unanimously.

The following Paper was then read and discussed:—

"Water Meters of the present day; with special reference to small flows and waste in dribbles;" by Mr. WILLIAM SCHÖNHEYDER, *Member*, of London.

The Meeting terminated at Ten o'clock. The attendance was 134 Members and 89 Visitors.

WATER METERS OF THE PRESENT DAY; WITH SPECIAL REFERENCE TO SMALL FLOWS AND WASTE IN DRIBBLES.

BY MR. WILLIAM SCHÖNHEYDER, *Member*, OF LONDON.

Although merely elementary knowledge, it is necessary to state at the outset that Water Meters are divided into the following classes:—

1. Low-Pressure Meters.
2. Inferential Meters.
3. Volume or Capacity Meters, without device for rendering them tight.
4. Meters of the Venturi class, which have a special function.
5. Waste-detection Meters, of the Deacon class.
6. Positive Meters, or Meters which provide a space to be filled and emptied of water, and which have some contrivance for rendering them tight at varying pressures and under diverse conditions of service.

Before treating each of these classes, it may be observed generally that they all have a useful purpose which they are capable of answering with more or less advantage, according to their individual merits. The mistake most commonly made, in the author's opinion, is that they are used indiscriminately, and frequently selected on account of first cost, without due consideration of the duty they have to perform.

The question next presenting itself is, what are the small flows to which this Paper has reference, and of what importance is the measurement of waste in dribbles? That all water supplied by private companies, intent on earning dividends, should be paid for, goes without saying, provided the cost of measurement does not exceed that of allowing the pumped, impounded, filtered, and delivered water to run to waste.

Table 1 illustrates the large flows of water represented by leakages through comparatively small holes, when under a pressure of 100 feet head.

TABLE 1.

Diameter of Hole.	Gallons.		Number of persons that can be supplied at 15 gallons per head per day.
	Per hour.	Per 24 hours.	
Inch.			
$\frac{1}{4}$	381	9,144	610
$\frac{3}{16}$	214	5,136	342
$\frac{1}{8}$	95	2,280	152
$\frac{1}{16}$	24	576	38
$\frac{1}{32}$	6	144	10

The quantities in the above Table are estimated, and are confirmed by experiment at Liverpool.

But a wider and more important question arises when the needs of our increasing population and the necessity of larger supplies come forward for consideration. Ten gallons per head per day of the London water-supply admittedly represents waste. This quantity, based on a population of 5 millions, is 50 million gallons per day, or sufficient to supply 25 gallons per head per day to an increased population of 2 millions: or, in other words, is more than sufficient for the needs of the City of Berlin. To put the matter (if possible) still more plainly, if this waste is permitted to continue, £8,000,000 of capital, or one-fourth of the total approximate cost of the proposed Welsh scheme of water-supply (of 200,000,000 gallons per day) to London, will be spent in order to make up the deficiency caused by preventable waste.

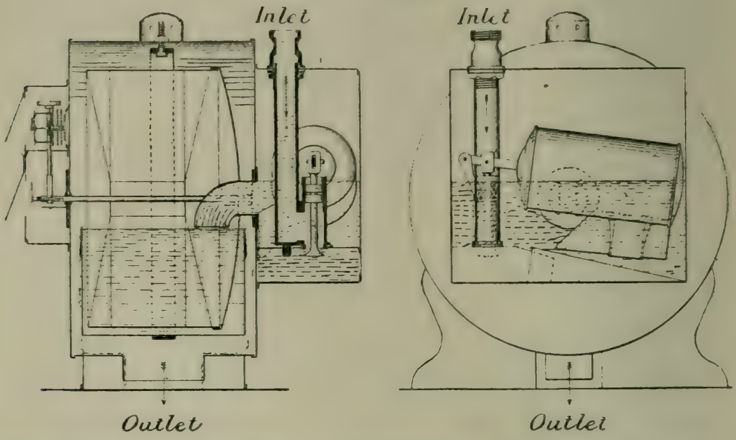
Here is a great problem; and the author believes the solution of it lies in the sale of water either by meter only (at very low prices it may be), or by meter with a fixed charge for a minimum supply at present rates in order to ensure health and cleanliness. He has devoted many years of his life to the production of an efficient instrument for the ordinary measurement of water, and especially for the purpose of registering dribbles; with what amount of success he must leave to others to determine.

Returning to the different kinds of meters already classified.

1. *Low-Pressure Meters.*—These are more especially applicable to measuring small flows, such as dribbling supplies to flushing cisterns, but they can also be used for such services as supplies to private houses in which cisterns are used. The great objection to them is, as their name implies, that the whole of the pressure from the main is lost in passing through them; and therefore they require to be placed at the highest elevation at or from which a supply is to be taken; and this again involves—in the case of house supplies—the frequent entry of the meter-inspector and assistant to the top of the house, for the purpose of reading the index, and examining, repairing, or exchanging the meter.

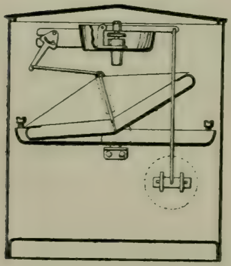
The oldest and probably the best known meter of this type is the "Parkinson," Fig. 1, page 40, which was described in a Paper read before this Institution (Proceedings 1851, page 19). In general appearance and also in construction it much resembles a gas meter; it has only one moving part, namely the drum, though it also requires at least one ball-valve for regulating the supply of water to it. The meter was again described in the Proceedings of 1882, page 41. It is very accurate down to the smallest dribble and will work a long time without requiring repairs. The quantity delivered by the smaller sizes however is rather limited, for a $\frac{5}{8}$-inch meter is only rated to pass a maximum of 100 gallons per hour, a $\frac{3}{4}$-inch 200 gallons, and a 1-inch 400 gallons per hour, or about one-third as much as meters of other kinds. In the larger sizes the supply is taken through two or more orifices of exactly the same diameter, but only that portion which passes through one of the apertures is measured, and the total flow is computed by multiplication in the clockwork. It would seem that large errors (plus or minus) could

Fig. 1. "*Parkinson.*"



easily accumulate by such an arrangement, through one or more of the openings becoming partly obstructed by impurities; indeed the author is informed that such is actually the case, when the water is not quite clean (see Mr. Ellington's Paper on Hydraulic Power Supply, Proceedings 1895, page 365).

Fig. 2. "*Bascule.*"



The "Bascule," Fig. 2, is another meter of the low-pressure type. Like the "Parkinson" it has only one moving part, which is in the form of a double bucket, mounted on pivots, and so arranged that when one of the buckets is taking its supply from the main, the other is being emptied, and *vice versa*; each bucket when full overbalances the other. In this meter also a ball-valve is required for limiting the supply. A meter of this kind was described by the late Sir William Siemens in the Proceedings of this Institution for 1854, page 6, and was called a "Bucket" meter; it was invented by Mr. Mead, of London.

Fig. 3. *Siemens' "Turbine."*

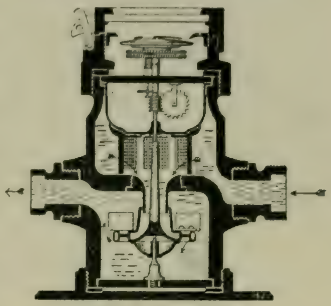
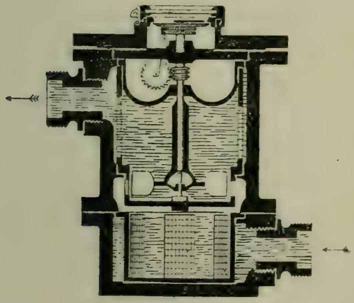


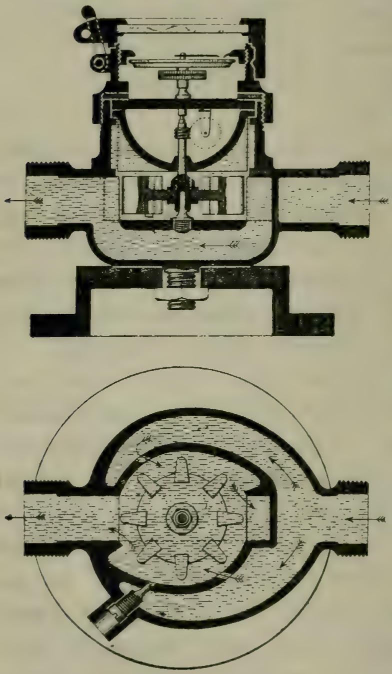
Fig. 4. *Siemens' "Fan."*



2. *Inferential Meters.*—As the name implies, the water is not actually measured in this type of meter, but the quantity passed through it is "inferred" from the number of revolutions made by the fan or turbine, which is the only moving part. These meters are exceedingly convenient and useful, as they are comparatively small, light, and cheap; and they are fairly accurate when the water passes through at a good speed, as when used for filling water-carts, for filling large tanks (without ball-valves), or for similar purposes. When however the flow of water through them is frequently slow, their registration is very unsatisfactory, as the fan or turbine then lags behind or stops entirely, while the water passes through freely. Probably the oldest and certainly the best known of this class was invented by the late Sir William Siemens in or about 1850. Two distinct kinds are made, namely the "Turbine," Fig. 3, and the "Fan" meters, Fig. 4. In the first, the water enters through the top of a vertically placed wheel with turbine-shaped buckets, and being discharged from these in a diagonal direction, the reaction of the water turns the wheel, which thereby actuates the clockwork of the dial. Retarding vanes on the wheel prevent it from running too quickly at the higher speeds. The footstep, also the top of the wheel-spindle, and the clockwork are lubricated with oil, which cannot readily escape; the clockwork arrangement is ingenious and effective. The "Fan" meter, like that of the

"Turbine" class, has an upright spindle, and is similarly furnished; but the wheel is driven by jets of water impinging on vanes secured to the spindle. In this country the turbine type is chiefly used, and abroad the fan type. The Siemens meters were fully described in the Paper which the inventor read before the members of this Institution in 1854 (Proceedings, page 6), and in Mr. J. J. Tylor's Paper (Proceedings 1882, page 43), and also in the Paper read by the late Mr. Henry Gill before the Institution of Civil Engineers in 1891 (vol. cvii., page 203). In the latter Paper is described an arrangement for causing the jets of water to strike the vanes of the fan meter always at the same velocity, with the view of causing the meter to register the small flows as accurately as the large flows; but the author does not think this plan is a success, as the floating cylinder (or shutter) is liable to set fast, if for any length of time the meter is idle or is only registering a constant flow. Attempts have often been made to obtain the same accuracy at all speeds of the inferential meter, by combining a large and a small one; but the author has no personal knowledge of the efficiency of this plan. The "Tylor Inferential," Fig. 5, is another well-known meter (Proceedings 1882, page 45); it is of the fan type, and the wheel is sometimes made of vulcanite, so that it practically floats in water, and the step has therefore no weight to carry, but acts only as a gentle guide.

Fig 5. "*Tylor Inferential.*"



A number of other types of inferential meters are made and used, especially abroad; they are far too numerous to mention, much more to describe. There is probably no great difference in their value. Vulcanite should count favourably in their construction; but they all fail to register small flows, yet in spite of this acknowledged defect they are habitually employed for measuring house services and other dribbling supplies with the result that the registered consumption, even in a water-closet town, is quoted at only 5 gallons per head per day, and less (see Mr. Gill's Paper, Proceedings, Institution of Civil Engineers, 1891, vol. cvii, page 239); whereas in reality this should be nearer 15 or even 25 gallons per head per day.

3. *Volume or Capacity Meters.*—These meters are almost exclusively made in the United States of America, and their use is chiefly confined to that country, though some are also used here. In construction they are broadly speaking all the same, as they consist of a casing of either gun-metal or vulcanite, in which works a vulcanite block, serving both as piston and valve. They seldom possess any provision for taking up wear, and the parts are therefore difficult and expensive to repair. Hence, though they profess to measure the volume passing through them, they cannot measure small flows, as they are not tight even when new, and their leaky condition is necessarily augmented by wear. Their merits appear to be simplicity, small size, lightness, and cheapness; and for large flows they are said to be very accurate. The "Hersey," Fig. 6, page 44, the "Crown," Fig. 7, the "Bee" or "Thomson," Fig. 8, the Kent "Uniform," Fig. 9, (Proceedings 1895, page 365) the "Nash," and some others belong to this class. Several of these meters, such as the "Bee" and others, are of the disc type, and are founded on the patent taken out in this country in 1830 by Edward and James Dakeyne, for an engine or pump; and later by Davis and Bishop. Only in the Kent "Uniform" has an attempt been made to compensate for wear, by means of a lever adjustable by a set-screw against the edge of the oval piston-block. The part of the lever however which bears

Fig. 6. "*Hersey.*"

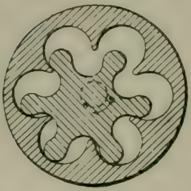
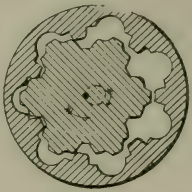


Fig. 7. "*Crown.*"



against the piston is tipped with glass, a material quite unsuited for such work on account of its brittle nature; and further, the lever is not automatically adjusted to the wear. Most, if not all, the other meters of the "Volume" type can be repaired only by mechanical manipulations requiring high skill, or sometimes by renewal of parts; though how new parts of standard dimensions can fit old and worn parts, where no adjustment is possible, it is difficult to understand. It appears from recent comments in the American press that the unreliability of these meters to record accurately the small flows to private houses &c. is being more and more recognised. When the water is not very clean, is rather hard, or for some time stagnant, the meter will set fast, while still allowing a large quantity to pass—of course unregistered. Judging from their general construction, and from reports of their workings, as well as from the author's own experiments, he fails to discover any advantage to be obtained from the use of these meters over those of the Inferential type. Indeed he has come to the conclusion that they do not equal in accuracy a well made and well maintained Siemens meter.

Fig. 8. "*Bee.*"

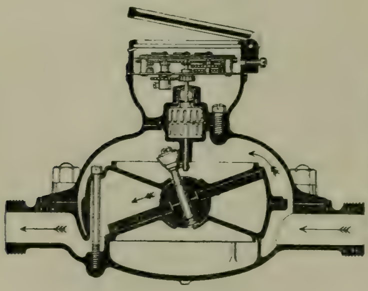
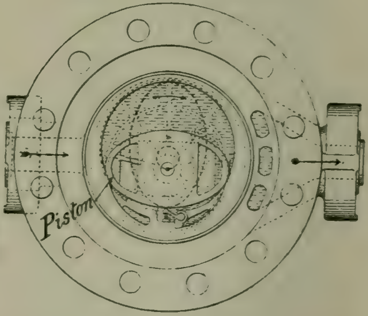
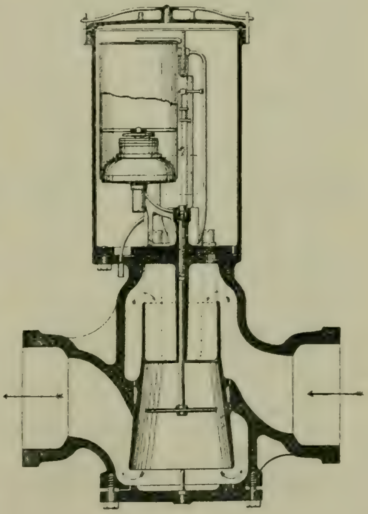


Fig. 9. *Kent* "*Uniform.*"



4. *The Venturi.*—The possibility of constructing the "Venturi" meter is due to the practical absence of loss of head in the main, which is contracted and again expanded by means of properly formed cones. The difference between the pressure where the water is passing through the main pipe before arriving at the meter, and where it is passing through the neck of the tube, forms the index for gauging the flow. These facts were discovered over a century ago by the Italian philosopher Venturi; and the meter has been perfected by Mr. Clemens Herschel of America. It has no moving parts, except the registering gear, driven by clockwork; it is cheap, considering the large volume of water it deals with, and for ordinary rates of flow in water-mains it is said to be very accurate, and it is certainly most convenient and useful; but it must of course not be used below its rated capacity.

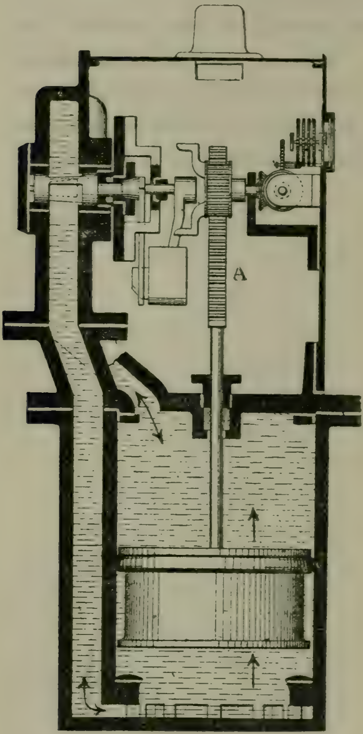
Fig. 10. "*Deacon.*"



5. *Waste-Detection Meters.*—A simple and effective meter of this class, Fig. 10, has been invented by Mr. G. F. Deacon of Liverpool, and it is in extensive use. The water enters the upper and smaller end of a conoidal tube (though in some of the meters it passes upwards from below), in which is mounted on a rod a circular disc, so as to be able to move freely up and down. As the flow increases, the disc will fall, and will rise when it decreases; its motion is communicated to a pencil outside the meter by a thin metallic cord passing through a gland, and suitably counterweighted. The movements of the pencil are traced on a sheet of moving paper with divisions representing hours, generally 24. A diagram is thus traced, which indicates to the initiated the varying flow through the main; and

the exact rate in gallons per hour can be measured for any time of the day or night, and by these means waste is readily detected. The total quantity passed is often computed by a special attachment; and can be read off on dials, as in ordinary meters. Several meter manufacturers make attachments to their instruments for obtaining similar results; and this is effected by causing a uniformly moved strip of paper to become marked with a line for every 100 gallons passed. This is of course convenient for many purposes; but for general waste-detection and locating, especially in large mains, the "Deacon" apparatus seems the more convenient.

Fig. 11. "*Kennedy.*"

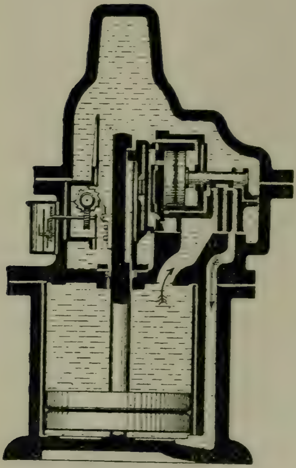


6. *Positive Meters.*—The aim of all positive meters is to measure accurately (positively) and record the water passing through them. Hence they have each one or more cylinders (with their pistons and valves), which are alternately filled and emptied; and of course they have suitable counters.

The "Kennedy" meter, Fig. 11, was brought out about 47 years ago, and it still retains its high reputation; it was described and illustrated in the Proceedings of this Institution for 1856, page 151, and 1882, page 42. It has a single, vertical, double-acting cylinder, with its piston packed with a rolling india-rubber ring, and a valve representing an ordinary plug-cock, but having a thin plug, which does not cover the inlet and outlet ports when at half stroke; hence little or no concussion is caused through the reversal of the valve, as the water is never quite stopped in its change of movement into one or the other end of the single cylinder. The reversal of the valve is effected by a tumbling weight, which is raised by the piston-rod in both its up and down strokes, and which in falling forces down a double-ended lever on the end of spindle of the plug-valve ; suitable spring buffers finally arrest its fall. As this method of reversing the valve does not produce uniform lengths of stroke at varying speeds of the meter, an ingenious counter is employed, which by means of suitable ratchets and pawls practically measures the lengths of each stroke, and adds them up, thereby producing a very accurate registration. These meters are of large capacity ; hence their movements are slow, so that the wear and tear of the parts are small ; and further, they discharge large quantities of water under small heads, or differences of pressure at inlet and outlet. The rolling piston-rings are now said to be very durable, but heavy shocks will sometimes cause them to slip from their proper position, and become damaged. The meter is very bulky and rather noisy. The valve when at mid-stroke leaves the inlet and outlet passages momentarily open to each other, so that for a very short time water can pass from inlet to outlet without entering the meter, and therefore without being measured. However, when the meter has been properly packed, adjusted, and oiled, the interval of time is so exceedingly small as not sensibly to affect the registration ; and this part of the construction has for the last few years been much improved by the adoption of Mr. Muirhead's arrangement, whereby the valve is started from rest by the movement of the piston before the tumbling weight falls over ; hence the work of reversing the valve is not entirely dependent on the falling weight, and the action of the valve is said to be now much more certain. According to the manufacturer's instructions, the meter requires to be cleaned, oiled, and generally to be seen to every month, and it is not recommended to place it underground ; but the author is well aware that the latter recommendation is far from being followed by users. This he believes is the only single-cylinder positive meter in use at the present time. The number of parts and of the special tools required for its repair, as well as the numerous directions for attending to the meter, indicate some of the disadvantages attendant upon the general use of it.

Nearly all the other types of positive meter have two measuring cylinders with their pistons and valves, and are of the "Duplex" class, in which the piston of one actuates the valve of the other. Some have their cylinders horizontal, and others have them vertical. The "Frost" or "Manchester," Fig. 12, has one cylinder vertical and the other horizontal; and they all have flat gun-metal valves, working in straight lines on gun-metal faces. The two cylinders of this class are nearly always of the same capacity, but in the "Tylor Positive," Fig. 13, there is a small difference in their size, and in the "Frost" there is a considerable difference in their dimensions. Why there should be this large difference between the cylinder capacities the author is unable to say; and he is still less able to explain why the valve supplying the small cylinder or cylinders should be so abnormally large, and why that supplying the large cylinder with water should be of such diminutive dimensions.

Fig. 12. "*Frost.*"



The best known "Duplex" meters are:—The "Frost," Fig. 12, (Proceedings 1857, page 175, and 1882, page 42); the "Tylor Positive," Fig. 13; the "Worthington" (American), Fig. 14; the "Frager" (French), Fig. 15, made by Michel (Proceedings Institution of Civil Engineers, vol. lxxxvi, page 444); the "Schreiber" (French), Fig. 16; the Kent "Absolute," Fig. 17, page 50, bearing a strong resemblance to the "Frager"; the "Goodwin," looking much like a "Worthington." The "Schmid" meter, Fig. 18, page 50, is also of the duplex type; but, unlike the general run of this sort, its pistons have their length of stroke controlled by a crank-shaft, cranks, and connecting-rods, and the piston of one cylinder serves as valve for the other. As the pistons have no packing, the meter is even worse than the "Worthington" meter, as both pistons and valves must soon become leaky with wear, and when new are apt to set fast with small impurities. The crank-shaft appears to require frequent lubrication from the outside. They are used abroad only; an attempt to manufacture them satisfactorily in this country utterly failed.

Fig. 13. "*Tylor Positive.*"

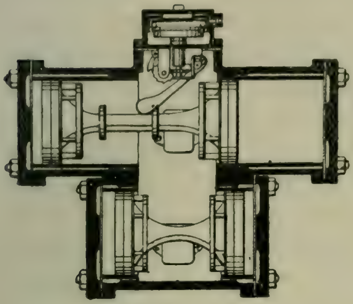


Fig. 14. "*Worthington.*"

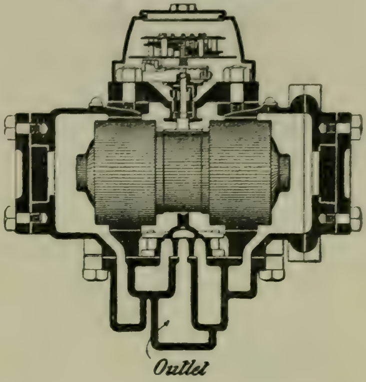


Fig. 15. "*Frager.*"

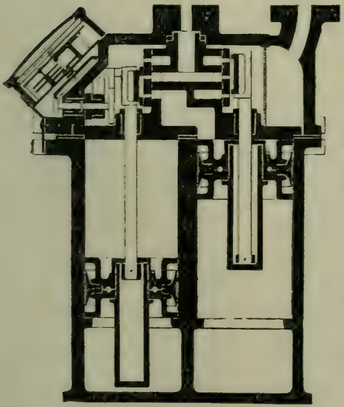
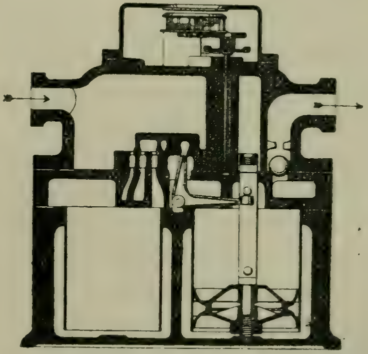
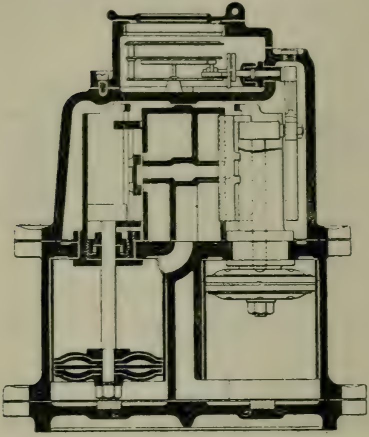


Fig. 16. "*Schreiber.*"



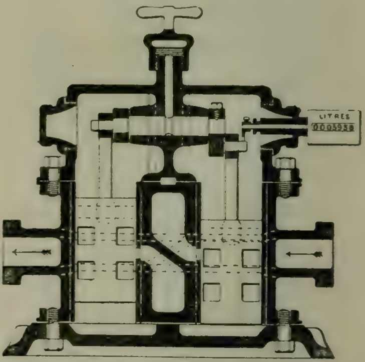
The piston packing in this class is generally of leather, which the author has not found in his experience to be the best material. In the Kent "Absolute," Fig. 17, it is a combination of leather for wearing surface, and of corrugated india-rubber discs for expanding the leather as it wears. In the "Worthington," Fig. 14, page 49, the pistons are intended to float in the water, but the author very much doubts their ability to continue to do this, after long exposure to heavy external pressures. They are further without any packing, like the discs or links &c. of the volume meters; hence they must be liable to set fast with dirty or hard water, and must become leaky with wear, and to repair them is an expensive process, as it involves renewal of four pistons.

Fig. 17. *Kent "Absolute."*



Several of the duplex meters ("Frost," "Frager," and Kent "Absolute") have stuffing-boxes, which require attention from time to time; and the slide-valves of all—on account of their limited and rectilineal movements—soon become leaky by ordinary wear, and in even moderately hard water they often become fixed or grown to their seatings, if left at rest for a short time. All meters of this class can be repaired only by skilled workmen, and must in all cases be removed to the workshop for the purpose. Several of them

Fig. 18. *"Schmid."*



are crowded with small screws, pins, and springs, which often give trouble by breakage; and the dismounting and re-assembling are tedious work in most of them.

Next in importance to accuracy, durability, simplicity, and general efficiency, must be considered the quantity of water delivered under a given effective head. Judged from this standpoint the "Kennedy," Fig. 11, page 46, is far ahead of all others; while the "Parkinson Low-Pressure," Fig. 1, page 40, the "Siemens Inferential," Figs. 3 and 4, page 41, and the "Tylor Positive," Fig. 13, page 49, are much below the average in this respect.

The difficulty of estimating the amount of water expected to be used in any prospective supply, or that used in an existing service, is strikingly illustrated in the Paper by the late Sir William Siemens (Proceedings 1856, page 116). Thus of the amounts supplied to fifteen consumers, firstly as estimated, and secondly as found by meter measurements, the value was £685 of the first, and of the second £4,170; and the author is fully convinced that it is not easier now to guess even approximately the amount of a certain water supply than it was forty-three years ago. Still, many water-works engineers are in favour of selling water by contract rather than by meter.

Early in 1884 the author's attention was directed by one of the largest London Water Companies to the great want of a good water meter, which should be free from the defects of those already in use, and which should above all be simple, and should be able to register the smallest dribbles for long periods without liability to derangement. After considerable study and not a few experiments he brought out his first meter in 1888. It was of the three-cylinder horizontal type, having a single flat valve with a double movement, which caused it to remain always tight; and the three-cylinder arrangement produced a steady flow, as well as quiet working. These meters were before the public for about seven years, and most of those made are still doing good service; but they were composed of too many working parts for thorough efficiency.

Further study, a few experiments, and assistance from the manufacturers, Messrs. Beck and Co., of Great Suffolk Street, Southwark, produced the present type, now called the "Imperial," shown one quarter full size in Plates 1 and 2. Here the single-acting three-cylinder arrangement is retained, as is also the double movement of the valve, now made with a hemispherical face; and there is the same absence of small screws and springs, while the dismounting and remounting are even simpler and easier than in the first type. It has however in its construction ten fewer moving parts; and therefore the force required to drive it, and the wear and tear, are much reduced.

The meter consists, as will be seen, of the following parts. The lower portion or body A, Plate 1, contains the three cylinders B, and the valve-seating C, with its three ports and passages D, communicating with the bottom of the cylinders; and there is a discharge port and passage E. Inlet and outlet connections F and G, and strainer H, Fig. 23, Plate 2, are also attached to the body portion. I is the cover, with the rib K for holding down the strainer; and it has a prolongation at the top for receiving the counter gear. The unequal spacing of the bolt-holes prevents the cover from being wrongly fixed to the body. Though the counter gear contains a few novelties—such as the entire absence of brackets, screws, springs, and small pins, and has a conveniently hinged glass cover — still essentially it does not differ much from the counters of other meters. L, Fig. 21, is the valve with its three arms, in the ends of which are cup-shaped bushes, for receiving the spherically shaped heads of the piston-rods M, Fig. 19; and to these are secured the pistons, composed of upper and lower piston-plates, nuts, and flexible piston packings. The water entering the meter, as shown by the arrows, passes up through the strainer into the upper portion of the casing, and presses equally downwards on all the three pistons, and also on the valve. According to the position of the valve, the lower end of each cylinder in succession is communicating with the outlet passage, and its piston is therefore forced down by the superior pressure above, and thus discharges the contents of the cylinder. At the same time one or both of the other cylinders is having its piston raised, whereby water is drawn in through the passages, and the lower part is filled. Thus each lower end of the three cylinders B is in due course filled and emptied, one or two pistons always supplying the active force, so that there is no dead-point. The length of the stroke is regulated by the flanged projection N on the valve L, Fig. 19, coming into rolling contact with a similar flange O on the valve-seating C; a slight skew of the ports causes the pistons to endeavour to take a longer stroke than they should, and the roller-paths restrict this tendency. The teeth in the valve and the notches in the valve-seating prevent the valve from turning round on its own axis, Figs. 21 and 22, Plate 2. A pin in the upper part of the valve engages the crank of the crank-spindle P, Fig. 19, which communicates motion to the clockwork in the usual manner. The pins through the upper ends of the piston-rods prevent the pistons from falling out of the cylinders, should the meter happen to be turned upside down.

From the above description it will be seen that the meter is positive in its action, that the lengths of stroke are definite, that the speed of water through it is practically uniform, as in a three-throw pump, so that there is no concussion or water-hammer; that there is no backlash between any of the working parts, and that the meter can therefore be run at any convenient speed without noise. It has few working parts, not a stuffing-box nor a spring among its details, and is self-lubricating. It contains no small parts, neither pins nor screws; the three studs and nuts (permanently securing the valve-seating), the cover-bolts, and the piston nuts are the only appliances of the sort used. As soon as the cover has been removed, the whole of the working parts can be taken out, examined, cleaned, new piston-cups fitted, and other ordinary repairs effected, if necessary, even without removal from its position in the pipe line. The only joint which has to be made is that between the body and the cover; and any leakage here is at once detected, as it is outwards. As to durability, the author has frequently been informed by users, who take out meters for repair every two years, that it has been a common occurrence to find they require only cleaning, painting, and re-testing, to be again fit for service; even the piston-cups often serve two terms, of two years each. The valve-faces never require any attention, as they soon polish themselves bright like mirrors, and remain quite tight.

In order to test for himself the practical working of this meter, the author had one of $\frac{1}{4}$-inch size affixed to the service pipe of his private house in February 1896, and tested it for accuracy at various times with satisfactory results. In May 1897 an American "Volume" meter of $\frac{1}{2}$-inch size, being the smallest he could obtain, was fixed tandem with the "Imperial," which was first cleaned and furnished with new piston-cups, so as to put both on the same footing. Both meters were tested before fixing, at various speeds, and were found to be practically correct, though the "Volume" meter was disinclined to register flows below about two gallons per hour. The service is partly direct through draw-off taps on the ground floor and basement; and partly through a ball-valve in the main cistern, for supply to bath, lavatory, and hot-water cistern. From 21st May 1897 to 20th May 1899 the "Imperial" had registered 100,248 gallons, and the "Volume" meter 81,772 gallons, or more than 18 per cent. less than the "Imperial" for the two years. As the inhabitants of this house do not allow dribbling wastes by leaky or half-closed taps to continue, the author feels certain that for an average house the readings of the two meters would have shown much greater difference. Weekly readings showed the "Volume" meter to be from 10 to 50 per cent. slower than the "Imperial"; and in one night of twelve hours in April 1898, when a leaky fitting had been discovered, the "Volume" registered only 5 gallons, while the "Imperial" registered 29 gallons; on another occasion, also of twelve hours, the figures were 9 gallons and 29 gallons respectively. The meters were tested from time to time in the two years, and both were found to be correct, excepting the "Volume's" objections to small flows. When the meters were tested in May of last year, the "Imperial" was practically correct at all speeds, down to 2 gallons per hour, below which it was not tried; while the "Volume" would not register 4 gallons per hour, and at 5 gallons per hour it was 10 per cent. slow, while at 48 gallons per hour it was practically correct. The rate of working in this house, according to a large number of observations, varies from a mere dribble up to 100 gallons per hour, which has been found sufficient for all purposes. These experiments, the author would submit, prove that the "Imperial" meter is in every way fitted for measuring supplies to private houses, in addition to its suitability for general use; and that a meter which will not measure the smallest dribble is misleading and costly for such service.

As comparative tests of different types of meters are but seldom recorded, the author thinks that the following results of tests of four meters, Table 2, coupled in line on the supply to a country waterworks, will be of interest. The supply was varied from time to time by hand, and each meter was tested for accuracy before fixing, with the results given.

TABLE 2.—*Tests of Four Water Meters.*

Meters.	"Positive."	"Inferential."	"Volume."*	"Positive."†
Initial Errors.	− 3 per cent.	+ 7 per cent.	+ 2 per cent.	+ 1½ per cent.
1889 4 February .	2,780	1,990	2,346	2,898
13 " . .	2,800	3,260	2,454	2,958
18 " . .	1,310	880	850	1,370
25 " . .	1,960	1,410	1,344	2,040
4 March . .	2,000	1,310	578	2,090
11 " . .	1,880	1,200	2,358	1,980
18 " . .	2,060	1,325	1,405	2,150
25 " . .	2,080	1,345	1,465	2,300
1 April . .	2,320	1,680	1,802	2,346
8 " . .	2,250	1,850	2,040	2,364
Totals registered .	21,440	16,250	16,642	22,496

Here certainly there seemed little to choose between an "Inferential" and a "Volume" meter; both were practically 25 per cent. slow on the average of the ten weeks' test.

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* This meter stopped several times. † The author's first type of meter.

In conclusion, the author trusts that he has neither claimed greater merits for the "Imperial" than are due to it, nor understated the advantages of other types; and hopes that he has not tired the members with descriptions and statements which may be familiar to many of them.

Discussion.

Mr. Schönheyder said that in making a new meter of the type shown on Plates 1 and 2, as in making any new machine, difficulties were very often met with at the outset, and he had found a few difficulties, which, however, had been completely overcome, although it took some time to find out their nature. These had been overcome by changing the material from which certain parts were made, and not in any way by changing the construction. The first parts to give trouble were the piston-cups. They had been at first made of leather, but it was impossible to get leather of uniform thickness or substance. Some of the leathers when placed in water became hard, some soft, some swelled, and some shrank. He had made many experiments, the result of which were piston-cups such as were shown. These were quite soft, and acted singularly well. They were made of a kind of vulcanite, or hard rubber. He did not know what substance was mixed with it, as that was the secret of the makers. The next difficulty was with the crank-spindle P, Fig. 19, of the meter, which had been made of gun-metal. The bush in which it worked was also gun-metal. After a time several of the crank-spindles seized in their bearings, and either stopped the meters or the counters. He then had the bushes made of vulcanite, and now the gun-metal crank-spindles worked satisfactorily. He had a further difficulty where the valve-pin touched the crank-spindle. It was found that sometimes the spindle and sometimes the crank wore away, which was probably owing to air accumulating in the top of the meter, and the two metals working together perfectly dry. Sometimes the end of the crank was cut completely away, and sometimes the pin, but by fixing vulcanite in the crank that difficulty was overcome. Further, in the counter-plate, where the pinion-spindle passed through the plate, there were at first two pieces of metal working together. These sometimes seized, but now the plates were always bushed with vulcanite, which had overcome that difficulty. He referred to the exhibits, which consisted of all the various portions of ½ and ¾-inch meters shown separately. The cylinders in the ½-inch meter, Fig. 24, Plate 3, were of gun-metal, but the cylinders of the other one were of vulcanite, which he found very useful in hard water, or when a meter had to stand still for any length of time. He showed two meters in action, one worked by water coming from a tank on the top of the building 90 feet above the platform, the other worked by a suction head of about 10 feet. The cover with its counter gear was taken away from the latter, to show the action of the valve and pistons. By turning on a tap the meters were made to move. In testing meters at the works a column of water, similar to that shown in the glass tube, was always used to see if the meters worked sufficiently free before they were sent out, and they generally worked with a 3-foot head. It also showed, when working very slowly, whether the meter was quite tight; if it continually dribbled, but did not move, it showed there was a leak in it. By turning the tap on a little harder a higher speed was obtained, and it would be seen that the stream of water was quite steady and the meter noiseless even at the higher speeds. There were two meters on the table which had been in use. The first had been kindly lent by the Southwark and Vauxhall Water Co. It was a ½-inch meter, Fig. 25, Plate 3, which had been in use two years and five months, and had registered 267,000 gallons. The company tested it before the seals were broken, at 450 and 20 gallons an hour, and it was found correct. After receiving it he had it tested down to 5 gallons an hour, and at that speed it showed a slight leakage of about half a gallon an hour. Members examining it would find there was practically nothing amiss with it, except that it was dirty, and probably the cups might require to be renewed after their 2½ years service. Cleaning and re-testing were about the most it needed.

(Mr. Schönheyder.)

There was also shown a $\frac{1}{4}$-inch meter, which had been in use at his house for two years, running tandem with a disc meter. It had been at work altogether nearly four years. The valve was quite perfect, as bright as gold, and tight. Nothing had been done to it. The cups were also in good condition after their two years' service. He had had it tested lately at various speeds from 200 gallons an hour to 2 gallons an hour, and it was practically correct, there being small errors of perhaps $\frac{1}{2}$ or 1 per cent. No lubricant was used on the valve except water.

Mr. J. E. H. DE KEY asked whether the discussion would be confined to the author's meter under discussion, or to the Paper as a whole.

The CHAIRMAN said that the discussion would deal with anything relating to water meters in general. As Mr. Hawksley was one of the greatest authorities on water engineering, perhaps he might wish to say something on the water meter.

Mr. CHARLES HAWKSLEY said he came rather as a learner than as an instructor in the matter of water meters. He had learnt a good deal about water meters during the last forty years, but he had not that intimate personal knowledge of their details which many of the members present possessed. It was generally known that each meter had its own defects; some of these had been described in the Paper as applying to a particular class of meter, such for instance as the inferential meter, which could not register very small quantities of water, although small quantities were matters of great importance to those who had water to sell. As would be the case in a large retail business, if the scales of the shopkeeper would not measure ounces, and he was obliged to give away everything, for instance, below a pound weight; the shopkeeper would not flourish, and so it was with those who supplied water; unless the meter would measure small quantities it was not very useful, especially in those many cases in which waste went on by driblets. He thought the different defects of the meters referred to had been touched upon so well in the Paper that it would be a waste of time to recapitulate them. He might state, however, with regard to the low-pressure meters, that the "Parkinson" meter, Fig. 1, page 40, had been found to give very good results during the many years in which it had been in existence. It had, of course, the great drawback that it would not transmit pressure. Then again there were defects which arose in many meters, good in the first instance, while they were new, but which ceased to register accurately because of the wear and tear of the various working parts, especially the valves. Further, most of the members would know that a meter would work very well with one kind of water, and yet when taken into another district or another town would be found to be a complete failure. Hard water perhaps would ruin it very rapidly by wearing the faces of the valves, whereas with soft water it would work admirably, or the reverse might be the case. Meters might be put out of order by rust in soft water districts, a difficulty which would be unknown in a hard water district. Having thus mentioned some of the general principles, on which depended the success or otherwise of any particular meter, he thought he might leave it to others who were better acquainted with the details of each meter to enlighten the members with regard to their various peculiarities.

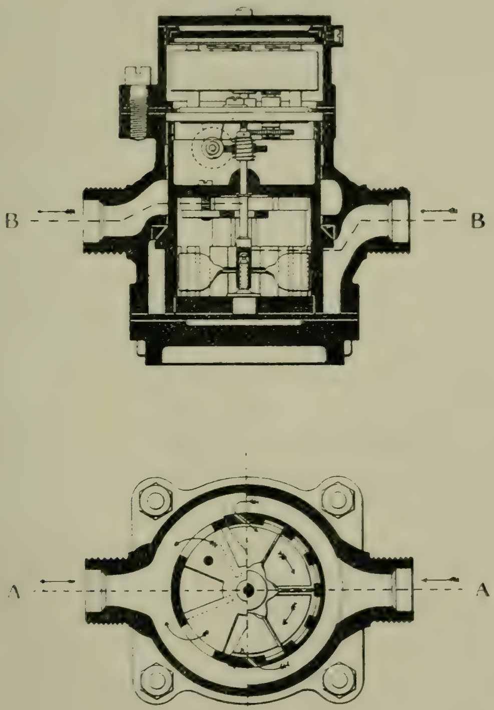
Professor W. CAWTHORNE UNWIN, Honorary Member, said he did not know that he was an authority on meters, but he should like to compliment Mr. Schönheyder on the very great ingenuity of the design of his meter, and still more on the patience with which he had investigated the causes of errors and eliminated them. He had read the Paper with very great interest, and there was only one passage in it about which he wished to make a remark or two. The author had mentioned the "Venturi" meter, page 45, although that was a meter which hardly belonged to the class which he was chiefly dealing with, and in mentioning the "Venturi" meter he thought the author was not quite accurate. In the first place the author rather implied that the principle of the meter was discovered by Venturi. Venturi made experiments on converging and diverging orifices, but he did

(Professor W. Cawthorne Unwin.)

not think he even noticed that a certain difference of head in the meter was proportional to the square of the flow. In the "Venturi" meter a certain difference of head was measured, which was proportional to the square of the discharge. That result can be deduced from the most general principle in hydraulics, the theorem of Bernoulli. The idea of using a pipe of this kind for measuring water was entirely original with Mr. Herschel. But there was another point which was of some practical importance. The author said with regard to the "Venturi" meter that it must never be used below its rated capacity. He believed he meant something perfectly right, but the expression conveyed a false notion that the meter only measured one rate of flow. Every meter would cease registering at some discharge or other—it might be a very low one, or one less low —but there was a point at which every meter would cease to register. In the "Venturi" meter, of course, registration did not go on to very low discharges, or rather registration went on all right, but it became too small to be useful. In other respects it had a range of registration like any other meter, indeed more—there was practically no limit to its registering large flows. It had been stated that as ordinarily constructed the "Venturi" meter ceased to register when the velocity in the main on which it was placed fell below about one-half foot per second. He had been informed that Mr. Kent had constructed a "Venturi" meter for a velocity, in the main in which the meter was fixed, as low as 0·1 foot per second. The "Venturi" meter was really very interesting. He had an opportunity of making some measurements with a "Venturi" meter on a water main 48 inches in diameter, and the meter had been constructed for mains up to 60 inches in diameter. It formed an extraordinarily accurate gauging instrument where flow in water mains had to be dealt with. There was another point he might mention. Mr. Schönheyder seemed to have found great advantage in substituting some form of vulcanite for metal, where the surfaces were in rubbing contact under water. That the author had found vulcanite answer so well reminded him of the extraordinary durability of lignum vitæ bearings when lubricated in that way. Lignum vitæ was used for the support of the propeller-shafts of steamships and for footsteps of turbines, and its durability when lubricated by water was extraordinary. In such cases the wear of metal bearings was very rapid.

Mr. PHILIP BRIGHT said he had only two or three remarks to make on the very interesting and fair Paper which Mr. Schönheyder had read. He was sorry the author did not let him know that he was going to illustrate the "Tylor" meter, because the one he showed, Fig. 5, page 42, had not been made for about eleven years, in fact the fan illustrated had not been made for sixteen years. The "Tylor" meter as now made was shown in Fig. 28. He could quite

Fig. 28. "*Tylor Rotary Meter, 1900.*"
Section on AA.



Sectional Plan on BB

(Mr. Philip Bright.)

bear out the remarks which Professor Unwin had made about the advantages of lignum vitæ (page 60). His firm had long used it in their large meters (8 inches to 12 inches), and found it most durable and entirely satisfactory. As to inferential meters, it was altogether a question of the size of meter which was employed. If small enough, they could be made to register very small flows indeed. Meters were made and were at work which would register 2 or 2½ gallons an hour perfectly accurately. Their capacity at full flows was not very great, it was true—about 120 or 140 gallons an hour—but as most of the water which was taken into houses for domestic purposes came through ball-valves into cisterns, he did not think this was a matter of great importance. He had lately measured some ball-valves stamped by the New River Co., and had found that the ½-inch ball-valve had only got ⅛-inch way, and the ¾-inch only 3-16ths-inch way. Turning to the author's Paper, he found it stated in Table 1, page 38, that ⅛-inch hole passed at 100 feet head 95 gallons per hour, or sufficient for a population of 152 people at 15 gallons per head per day; while a 3-16ths-inch hole passed 214 gallons per hour, or sufficient for a population of 342 people at the same rate of supply. Therefore an inferential meter costing only twenty to thirty shillings was quite capable of supplying the largest house with water, if the supply were a constant one—which he was glad to say was the case almost everywhere at the present day—and the house were fitted with a cistern, as all houses should be. The author had made some tests of a ¼-inch positive and a ½-inch volume meter, page 54, but did not say what the respective costs of those two meters were. He, the speaker, found from the author's figures that the positive meter—assuming the charge for water to be 1*s*. per 1,000 gallons—produced a revenue of about 3*d*. per week more than the volume meter. He thought that the question of the original cost and the expenses of maintenance should also be given, so that it might be determined whether the 3*d*. a week was really revenue, or whether it was balanced by interest on capital and repairs. With regard to Professor Unwin's remark (page 60) about the friction of metal working-parts in metal bearings, he thought many people had found out that metal and vulcanite gave better results. He believed Lord Kelvin's famous tap was originally made with a gun-metal valve and seating, but that the metal valve had now been superseded by a vulcanite one, the seating still being of gun-metal. As to water meters in general, they were not used for domestic supplies in England to any great extent, though they were in many other countries, and he thought the question of leakage in mains had a great deal to do with it. He saw it stated recently on official authority that the main waste in New York was 36,000,000 gallons a day; and it must be very large in London. If the author and other inventors could contrive a water meter which would register accurately, and charge to consumers all the waste which existed in water companies' mains, he believed that that meter would be universally adopted.

Mr. W. B. BRYAN said he had not expected to be called upon so early, and should have preferred to wait until he had heard what other inventors had to say in connection with their meters. He had suffered a great deal from inventors of meters, and other water-works engineers had probably done so also. He was responsible for looking after a revenue of £150,000 a year through water meters, and naturally such a large revenue required a great deal of care and study of the different types of meters. He thought there was room for several types of meters in all large waterworks. For instance, a positive meter could not be used for large supplies like those of railway companies and large manufacturers. Some of his company's supplies went as high as 300,000 gallons a day, and in such cases it was necessary, of course, to use inferential meters, and in these instances they registered with very considerable accuracy. For domestic and other small supplies an inferential meter perhaps was not quite as good as a positive meter, but the inferential meter had its advantages, as also had the positive meter. The positive meter sometimes stopped, and then the company would receive a sharp letter from the occupier of the house to know why his supply had been arbitrarily cut off by the water company. On the other hand, if an inferential meter stopped registering altogether, it did not stop the supply. That was an advantage to the consumer, but a little

(Mr. W. B. Bryan.)

disadvantage, perhaps, to the water company. The author had stated (page 39) that the sale of water by meter universally would have the great advantage of reducing waste. No doubt it would. On the other hand the cost of the meter and the meter rent in some districts would be very prohibitive. When he mentioned that his company alone supplied water to over 80,000 houses at a rental of less than 3*d*. per week, and perhaps 20,000 houses for 2*d*. a week, it would be seen that there was not much margin to pay for and keep in repair a very fine positive meter like the author's. And when he also stated that his company had 210,000 houses to supply, that the cost of a positive meter for each of those houses would be considerably over a million of money, and the annual cost of keeping them in repair would also be large, the members would see what a great business it would become. There was no doubt, on the other hand, that it would save capital by obviating the necessity for going further afield for water as early as would otherwise be the case, as the districts increased. With regard to the supply of water by meter to houses abroad, it should be remembered that in a city like Berlin the number of inhabitants per house was about 60, and in Vienna 69, consequently an inferential meter might be put in and register fairly for 69 or 70 people, but this would not be the case in London, as the average number of people to a house was only 6 or 7, or in the provinces only 5. It would therefore be seen that there was considerable room for inferential meters for large manufactory supplies, and for positive meters for smaller supplies. With regard to positive meters, he believed the "Kennedy" meter, Fig. 11, page 46, had many advantages over every other type of meter. Of course it had the disadvantage of bulk, especially in London. The author's meter was a distinct departure from every other type of positive meter. He thought very highly of it, and had to congratulate Mr. Schönheyder on the ingenuity that he had displayed in making such a meter. He might say a word or two about the "Deacon" meter, Fig. 10, page 45. This was used, as was well known, for detecting and helping to localise waste in the streets. His company's district, requiring sometimes 50 million gallons a day, was entirely governed by "Deacon" meters, which were most wonderful pieces of machinery for aiding water-works engineers in detecting waste and localising it. As regarded the "Venturi" meter, that had great advantages in enabling one to gauge the flow pretty accurately through very large mains. His company had one on a 48-inch main, and the water had been checked by cubing a large reservoir through which the water had passed, and its registration was found to be very accurate. The great disadvantage the "Venturi" had for commercial purposes was that if the clock stopped, the registration stopped, and that would not suit waterworks companies.

The CHAIRMAN said he understood that Mr. Kennedy, the inventor of the "Kennedy" meter, was present, and the members would be glad to hear him on the subject.

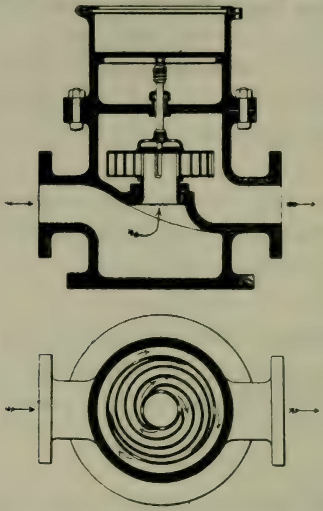
Mr. THOMAS KENNEDY said his remarks were written and were in the hands of the Secretary. He was afraid they were rather long and abstruse, but they would probably be printed with the discussion. [*See page* 79.]

Mr. ISAAC SMITH said that, as no reference had been made in the Paper to his meter, he had been invited to show the model exhibited on the table and illustrated in the accompanying Fig. 29, page 66. The subject of water meters had occupied his attention for many years. His father, the late Sydney Smith, made a water meter fifty years ago on the principle of the gas meter. It worked very well, but having other inventions on hand the subject was dropped. He himself had brought out a meter in 1893, based upon the principle of a continuous spiral passage from the centre to the periphery of the drum, and having three ports of discharge. Owing to the difficulty in balancing the motor, excessive wear resulted. Last year he invented the device in which a series of spiral channels were incorporated in the drum, in place of one continuous spiral as in 1893. These spiral passages had a gradual taper from the inlet to the outlet ports, and were constructed so as to give perfect equilibrium to the drum. As will be seen from Fig. 29, they were cast within the motor. They may however be made of an alloy that admits

(Mr. Isaac Smith.)

of their being pressed out by a die. The sleeve of the drum had an upper and lower bearing, which rode upon the port box. There were four port holes. The walls of the entrance of the channels were so enlarged that only one port-hole was able to supply one channel at the same time. By this arrangement congestion of fluid at the entrance of the channels was effectively prevented. The port box being terminable, all sudden or violent pressure was resisted by this contrivance, and the irritation produced by shock was spent before the water emptied itself into the case of the meter. The following details showed the proportions of the drum and the method of describing the curves :—

Fig. 29. "*Smith's Rotary Meter*, 1899."



No. of spiral channels in the drum . . = 3
No. of outlets " " " . . = 3
No. of inlets in port box . . . = 4
Outside diameter of port box . . . = Inside diameter of inlet pipe.
Area of the three spiral channels at inlet. = Half area of inlet pipe.
Area of the three spiral channels at outlet = Quarter area of inlet pipe.
Length of spiral channels . . . = 1⅙th revolutions.
Depth of spiral channels . . . = 2½ times the width at inlet.
Width of inlet and outlet ports . . = ⅙ diameter of inlet pipe.

Example for 1½-inch Meter.

Area of 1½-inch pipe = 1·767 square inches.

Area of three spiral channels at inlet = $\frac{1 \cdot 767}{2}$ . . = 0·883 square inch.

Area of each spiral channel at inlet = $\frac{0 \cdot 883}{3}$ . . = 0·294 square inch.

$$\text{Let } x = \text{width at inlet, then } x \times \frac{5x}{2} = 0 \cdot 294 \text{ square inch.}$$

$$5x^2 = 0 \cdot 588 ; \; x^2 = 0 \cdot 1172$$

$$\text{therefore } x = \sqrt{0 \cdot 1172} = 0 \cdot 342$$

Depth = $0 \cdot 342 \times 2 \cdot 5$ . . . = 0·855 inch, approximately ⅞ inch.
Spiral channels at inlet . . . = 0·342 inch wide, 0·855 inch deep.
Spiral channels at outlet . . . = 0·171 „ 0·855 „ „
Thickness of channel walls . . = $\frac{3}{32}$ inch = 0·0937 inch.

This meter possessed the advantage that there was no thrust either upwards or downwards, thus giving to the spindle free action in working the worm and recording wheel work without the slightest tendency to jam. It had proved upon the whole satisfactory when tested with normal and abnormal flows. When put to severe tests in different ways under pressure of 1 lb. to 80 lbs. and a dead head of 18 inches, it had responded with encouraging results. He had seen the drum in a small meter rotate quickly with a head of 12 inches, and the motor when fixed in the instrument could be blown down by a breath of air. He was not going to say it was a perfect meter, but what it needed was greater perfection in the quality of the clock-work.

Small flows and waste in dribbles had been made a special point by the author in dealing with his subject, and while, from a dividend point of view, and especially under the control of a private company, this was a matter of financial consideration, yet from a ratepayer's point, or on sanitary grounds, this economy might not turn out to be a paying one for the community, as it would tend to increase the risk of zymotic diseases. It would be a mistake to withhold the water-carts from the streets on account of cost; and when scarcity existed, the remedy ought to be sought in obtaining new supplies or an increase of pumping capacity. In the case of corporations being the proprietors of the water supply, their first care should not be

(Mr. Isaac Smith.)

directed towards lowering the rates by profits, but to keeping down the death rate by a liberal flushing of drains and a frequent use of the hydrant, especially in narrow streets and thickly-populated workmen's districts. No mention was made in the Paper with regard to different qualities of water met with in various localities. While some were comparatively free from the formation of silt, and afforded favourable conditions for the working of water meters, others held a good deal of matter in solution and rendered in a short time their accurate measurement a failure.

Mr. EDWARD B. ELLINGTON, Member of Council, said it was somewhat curious that the low-pressure "Parkinson" meter, Fig. 1, page 40, which could not register pressure, was the one that was largely used for the high-pressure hydraulic-power supply in London. The exhaust was registered, as it was only the pressure and not the water that was used, and the "Parkinson" meter had been admirably adapted for that purpose. The great difficulty with that meter was that it registered with perfect accuracy when the water was pure, but as the water registered passed through the machines it became contaminated with grease and bits of packing and so on, and a great deal of difficulty arose with it in consequence of the filling up of the drums, the meter thereby becoming inaccurate. There was another difficulty about the "Parkinson" meter in general use, namely, that it was a large meter, and in some cases a portion of the flow only was registered, when it became really an inferential meter. The accuracy of that meter for the larger sizes depended upon the same quantity of water passing through one, two, or three by-passages, of which only one was actually measured in the drum. To that extent therefore it was an inferential meter. With regard to the power supply, there was often, too, a difficulty in registering with the "Parkinson," because the water had to be passed first into an open tank and then from the tank to the meter. This was often inconvenient, and closed meters had to be used. The meters of the closed type, which had hitherto been used, had been principally of the Kent "Uniform" type. That meter had proved very satisfactory. As the author had stated (page 43), it would not register very small flows, except for a short time after being put to work, and it was therefore necessary frequently to change the working parts. Kent's was the first meter applied for the registering of high-pressure water. Fig. 9, page 44, showed the application of that meter to the registration of high pressures. Most satisfactory results had been obtained, but there was still a considerable quantity of water passing through the various meters in dribbles. The only difficulty that arose with regard to the most perfect meters that could be used, such as the author's, was their relative cost, as had been pointed out by Mr. Bryan (page 64). The question of the cost of the meters in reference to dribbles was a very important one. The size of the author's meter was considerable in relation to its flow, as compared with, say, the "Kent." He thought the author was to be congratulated on the results he had obtained, and he hoped to have a further opportunity of testing his meter in connection with the hydraulic-power supply.

Mr. GEORGE COCHRANE said that many different types of meter were used to register water in the hydraulic system with which he was connected; but in Manchester he believed they used entirely the high-pressure meter of the Kent "Uniform" type, and he understood the registration there was very good indeed; as much as 98 per cent was registered in twelve months, and even over a period of four years the registration had been as high as 98 per cent. of the actual consumption. That was very good, and such a percentage could not be claimed in London. He thought it pointed to what could be done with meters under general conditions. There was also the advantage of not using a meter which stopped the flow in case of any breakdown. A positive meter had always that danger, particularly in hydraulic supplies. The stoppage of flow in such places as wharves, warehouses, and to steamship companies, was very serious indeed; and it was much better on the whole that some of the water should be lost, rather than that a serious responsibility should be incurred by any stoppage of the supply. With a registration of 98 per cent. he thought everyone concerned should be satisfied.

Mr. T. A. **Wheatley** said that, being a member of the firm manufacturing the meter invented by Mr. Schönheyder, he felt he was precluded from criticising the various makes described in the Paper; indeed he had no desire to do so as he thought the Institution was as much interested in the general question of the sale of water by meter (with special reference to the use of those of a positive type), as they were in the relative merits of appliances contrived for this purpose. It was stated many years ago that anyone producing a really reliable positive meter would find an enormous demand for it; it could hardly be said, however, that the combined output of meters of this class justified the prophecy. It might be urged that no one had as yet produced a positive meter which was an unqualified success; at any rate, a number of inventors and manufacturers had done their best to deserve it. He himself thought there were important reasons why positive meters were not more generally used than they were at present, and it was to several of these he asked permission to draw attention. One of them was the question of price. He was aware no substantial reduction in the selling price of positive meters had been made, the cost of which was appreciable; and regretted that, considering the capital and ingenuity which had been expended in the effort to cheapen them (in order to increase the demand), he did not see much prospect of improvement in this respect, especially in view of the onerous duty they had to perform, and the limitations which surrounded them. But what meter makers asked them to consider (in conjunction with first cost) was the earning capacity of the instruments and the comparatively small cost of upkeep. They claimed that by the use of positive meters, notwithstanding the initial cost, dividends could be earned and waste checked more effectually and cheaply than by any other means at present available. The next obstacle appeared to be the commercial immorality of the manufacturer, for, although any statements he might make as to any other of his productions were generally accepted as being approximately correct, this was not the case when they had reference to a water meter. He ventured to suggest that this reputation might not be wholly due to their faults and failures, but to some extent to a lack of appreciation of the conditions under which it was reasonable to expect a meter to work satisfactorily. In order that a locomotive should do its work effectively and economically it was necessary to reduce mountains, raise valleys, metal roads, and lay rails; in fact, everything in this case was done to adapt the conditions of work to the machine. But this was not so in the case of a meter; it was too often stuffed into the ground without reference to its suitability for the duty required of it, and without any effort to bring the conditions of service within the range of the meter used. Care was of course taken to read the registration from time to time, but beyond that a meter was left to take its chance. If therefore in the course of a few decades it showed signs of wear or leakage it was not surprising; the best recommendation he could offer under such circumstances was that the owner should send it back to the maker and demand a new one to replace it. A water meter had no governor to protect it from being overdriven on the one hand, and it was not a pressure-producing instrument on the other. It made a useful air vessel, though it was not designed to serve in that capacity; it was not even an eel-butt or a mud-sumpt. He therefore appealed to the members to interest themselves more in the question of favourable working conditions for meters, as he felt it would pay them to do so. In one respect he admitted that meter makers were to blame, as they continued to designate the size of meters by that of the pipe to which they were attached, without reference to height, diameter, or even capacity in gallons per hour. In deciding on the size of the meter to be used, he suggested that not only the average quantity of water to be passed in the twenty-four hours should be accepted as a guide, but the maximum flow during any part of the day. He submitted, finally, that the most important reason why water meters (and especially those capable of measuring dribbles) were not in more general use was because public authorities, while alive to the necessity of a plentiful and pure water supply, failed to realise that preventable waste represented so enormous a percentage of the water supplied to consumers; they did not recognise the fact, which would probably dawn on them sooner or later, that the solution of the problem of meeting the needs of our rapidly increasing population

(Mr. T. A. Wheatley.)

lay as much in conserving what we already possessed as in enormous expenditure for increasing it.

Mr. WILLIAM MORRIS, engineer of the Kent Water Works, said he had taken great interest in meters for a long time, and thought Mr. Schönheyder's meter was one of the best. Mr. Schönheyder had frequently discussed the subject with him. Until he knew the results, after some years' working with those he had in use, he could hardly say whether it would be worth while to pay a larger price for them than for Siemens' inferential meters, Figs. 3 and 4, page 41, which generally worked very well. In the case of his company, domestic supplies were not given by measure; but there were a great many meters attached to private houses where, in addition to domestic supplies, water was taken for watering the gardens, and where it was important to impose some sort of check on the quantity of water used for this purpose, because it was taken from the mains at the hottest time of the year, and when the demand for all purposes was at its maximum. Unless some check was placed upon the water used for gardens, it was frequently allowed to run day and night on the grass plots. His company had established a system of requiring the water to be taken through a meter when required for the garden, charging, in addition to the ordinary rate for domestic purposes, something for the rent of the meter. Supposing, for instance, the water-rate of a house to be £4, his company asked £5 a year, or rather £1 5*s.* per quarter, for which the consumer would be entitled to use, say, 20,000 gallons. Consequently they were not so much concerned with the absolute accuracy of the meter in registering dribbles, the meter being fixed to act as a check upon undue consumption. In the great majority of cases it was found that the residential supplies did not exceed the quantity covered by their minimum rate, which was sufficient to give all the water that was required for gardens if it was used in moderation. But where consumers had very large gardens, or used water lavishly, the charge for water went far beyond the minimum rate. In such cases Siemens' meter seemed to be a very satisfactory one. In 1884 he went over to Berlin on behalf of the London water companies to investigate the way in which that city was supplied by meter. It was at the time when a proposal was made that Londoners should have the option of taking their water by meter. He found in Berlin that the Siemens' meters were very satisfactory, because there were no cisterns whatever in the city, all the supplies being absolutely direct from the main, and when water was used, it was drawn at a considerable speed. In Berlin nearly all the houses were built in flats, and held from 70 to 100 and more inhabitants. Under that system he found that the landlord paid for the water supply for the whole of the premises, and therefore it did not matter to the individual consumer what he consumed, as he had to pay a fixed charge. The landlord in every case was bound under the police regulations to have a representative on the premises, and that representative could read the meter and see that there was no excessive consumption. At the time of his visit, under that system, about 12 gallons a head per day were being used in Berlin, but he believed more was being used now. When they tried to supply each separate family through a meter they had to put in a smaller meter, through which people could not get enough water to fill their pails in the proper time or flush their closets. Therefore an inch meter was the smallest they used. Under those circumstances the result was very satisfactory indeed. He believed there was a loss of only about 8 per cent. in the difference between the water assumed to be pumped by the engines and the water sold through the meters to the inhabitants of the city.

The Chairman intimated that the Institution would be very pleased to receive any written remarks on the Paper that any gentlemen connected with London or country water works might be pleased to send in. The Secretary had already received five or six letters on the subject, with remarks which would be added to the Discussion in the Proceedings. [*See pages* 77–86.]

Mr. J. Macfarlane Gray said he would not like the meeting to close without adding his voice in commendation of the great ingenuity displayed by Mr. Schönheyder in his meter. He had read

(Mr. J. Macfarlane Gray.)

the Paper with great care and studied the drawings and tried to think out, while reading it, the geometry of the motions of the parts. He commended all young engineers to do the same. He considered the meter to be a poem in engineering, and congratulated Mr. Schönheyder on his work.

The CHAIRMAN said that before closing the meeting he should like to say a few words. Many of the members were there to grind their own axes, and he also had an axe to grind. The members were well aware that the Government were establishing a Physical Laboratory. That was, they agreed to grant £12,000 to start the laboratory and to spend £4,000 a year in the management of it. In addition to a lot of experimental work which would be carried on, it was desired that a large amount of testing should be done, and he believed that if the physical laboratory would take up the question of testing meters some good might be done. In making some recent experiments, he wanted to get some perfectly reliable meters, and on enquiring if they could be tested, he found that there was nobody in the country who could test them. All he could do was to get two meters from the same manufacturer and try them together. He did not think that was a satisfactory way of having the meters tested, and desired to ask Mr. Schönheyder and the members whether they thought it would be worth while for the Physical Laboratory to spend part of the government money in putting up an establishment, where government testing could be done at a small charge for each meter. He felt sure the members would accord a hearty vote of thanks to Mr. Schönheyder.

Mr. SCHÖNHEYDER, in reply, thanked the members for the very kind way in which they had received his Paper, and also for the high praise which most of them had given him for the production of his meter. He had to apologise for his error in describing the "Venturi" meter, and he was obliged to Professor Unwin for the correction (page 59). In speaking about the meter not being used below its capacity, that, of course, applied to all meters. His idea was that, if a "Venturi" meter were placed between two companies' mains so as to ascertain what water went from one company to another, at certain times of the day the flow would be so small that the meter would not register correctly. He thought Professor Unwin gave the minimum measurable speed of water in the "Venturi" meter to be one-half foot per second. This speed would deliver a very large quantity of water through a large main. With regard to Professor Unwin's remarks about lignum vitæ (page 60), he had used it, and thought at one time of using it very largely. He had fitted lignum vitæ in the bushes of the arms, and some of them had worked exceedingly well, though it had often dried and split. In preparing the various illustrations for the Paper, he had not intended to represent meters in their very smallest details as they were now made. If Mr. Bright would kindly lend the more recent drawing to the Institution he had no doubt it would be inserted with his remarks (*See* Fig. 28, page 61). Mr. Bright also spoke of using small inferential meters in registering supplies to houses. If a small meter was used a small delivery was obtained. The meter could not be used for both purposes, for measuring the dribbling supply to the house and for measuring large supplies. In his own house, the volume meter was fairly good down to about two gallons an hour, and in spite of that the difference in registration between this and his own make was enormous. In the night, when the flows were very small, the volume meter would hardly register, but his own meter kept on registering. As the result of two years' working there was a difference of about 18 per cent. If a large supply was wanted for gardens it must be had, and the small meter could not be used for such purposes. With regard to cost, the volume meter of which he spoke was very low, but it would now hardly register five gallons an hour, and how to repair it he did not know. It cost only £2, but that was very dear if 18 per cent. was lost by using it. The small quarter-inch meter which ran tandem for two years was only listed at £3 7*s.* 6*d.* It had had one new set of cups in that time, and as it stood now it was ready to work again, registering correctly down to two gallons an hour, and probably much less. Many water superintendents contended that if a meter registered down to five gallons an hour that was quite enough for all purposes. But if such

(Mr. Schönheyder.)

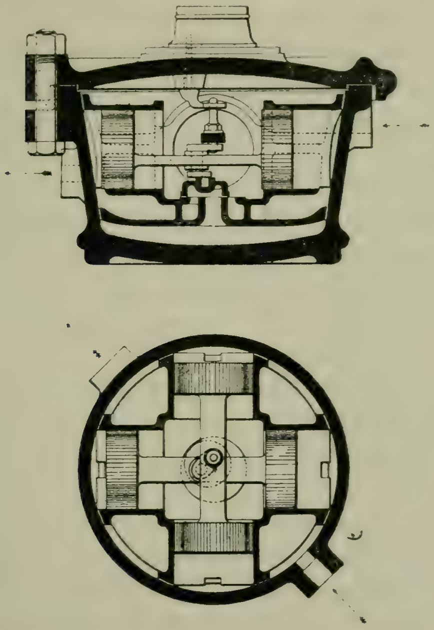
a meter was tried tandem with a correct meter that would measure small flows, the error would be seen at once. In his Paper he had pointed out that inferential meters were suitable for all large supplies, and he held with that still. As to the high cost of measuring water by positive meters, he might state that a good many "Imperial" meters were at work where only 4*d.* was charged per 1,000 gallons, and it was found advantageous to use them. With regard to the difficulty of measuring the water to small houses, or small flows, there was no reason why one meter should not be put to two or three houses. In one town where the whole supply was measured, a meter was put to four cottages, and this arrangement was found to work capitally. Mr. Morris had spoken about the great advantage arising from using the "Siemens" meter (page 72), but he was sure Mr. Morris was quite unaware of the amount of water lost, especially if he used the meter for house supplies. If he would be kind enough to put a correct positive meter tandem with one of his inferential meters, he thought interesting information would be gathered. He approved of the system of giving people a certain minimum quantity for a fixed yearly payment, but in comparing the Berlin supply with that of London, it must be remembered that in Berlin there were about sixty people to each house, in which case it was a very easy matter to measure the water by an inferential meter. He thanked Mr. Macfarlane Gray for his kind remarks (page 73); and entirely agreed with the Chairman's suggestion that it would be valuable to have a proper testing place for meters. [*See also page* 86.]

The CHAIRMAN added that he had asked the question about the Laboratory because he was the representative of the Institution of Mechanical Engineers on the Council of the National Physical Laboratory, and he therefore welcomed any suggestions upon the subject.

Communications.

Mr. Joseph Bernays wrote that he greatly appreciated the ingenuity displayed in the author's invention, and, having himself worked for some time in the same direction, had pleasure in submitting particulars of his own positive meter, patented in 1895. This meter, Fig. 30, consisted essentially of two pairs of short cylinders cast together round a central space, with their centre lines at right angles to each other. These cylinders were fitted with pistons connected together rigidly in pairs by short rods which crossed one another and were jointed in their middle by a plain link. As the pistons reciprocated, the link turned completely over,

Fig. 30. "*Bernays' Positive Meter*, 1895."



(Mr. Joseph Bernays.)

determining thereby the movements and strokes of the pistons. At the same time the centre of the link described a circle around the crossing point of the two connecting rods, which movement was utilised for working a circular slide-valve for distributing the liquid to the four cylinders. All parts dropped into their places without any internal screws or fastenings. Fig. 30 represented an encased meter of this construction, but if preferred the cylinders could be fitted with end covers, and the outer casing dispensed with.

Mr. HARRY FRANCIS, engineer and manager of the Devonport Water Works, wrote congratulating the author on the Paper, and on the fair manner in which he had stated the case of meters of various makers. He quite agreed with the statements in the Paper, and would lay stress on the author's remarks on page 37 that the mistake most commonly made was that meters were indiscriminately used without due consideration of the duty they had to perform; and he did not hesitate to say that there was not a meter in the market suitable for every supply which a water-works engineer was called upon to give by measurement.

He had had some experience of the author's meter, and had found it to work very satisfactorily. It was the best meter he knew of for measuring the supply to urinals with flushing tanks, which were supplied by what might be termed "dribbles." He had one of the author's first meters, a ½-inch meter No. 106, supplied to him in June 1888. This meter had been constantly working since that time; it had had no repairs executed to it, having only been removed a few times, cleaned, and again refixed. It had been removed during the past week, cleaned, and tested, the result being that for a measured quantity into a tank of 1,000 gallons the meter registered 1,000 gallons. The "Imperial" meter had but one fault, that was, that the first cost was great compared with other meters.

Mr. FRED HUNTER, engineer and manager of the Sevenoaks Water Works, wrote that, so far as his experience of thirty-five years went, he must pin his faith to the "Kennedy" meter, Fig. 11, page 46, for all purposes, but, like any other machine, it must be attended to. He regarded the Siemens' meter as next in efficiency.

Mr. THOMAS KENNEDY wrote that he thought the author had evidently given the subject much study, and had dealt with the various types in a very unbiassed manner. When intermittent supply was the rule, the measuring of small flows was unimportant. With constant supply, the author clearly showed its importance. In some cities, such as Paris and Brussels, where domestic supply was metered, no meter of the smaller sizes might be fixed which would not work with a flow of two litres per hour.

On page 48, the author, in describing the "Frost" meter, Fig. 12, said he was "unable to explain why the valve supplying the small cylinder should be so abnormally large, and why that supplying the large cylinder with water should be of such diminutive dimensions." This was a necessity in all meters of this class. The main piston had no work to do until it reached nearly the end of its stroke; then it had merely to move a small pilot valve. This valve directed, alternately, the water into the ends of the small cylinder, the piston of which moved the large cylinder valve. If the main piston was allowed at high velocities to strike the cylinder ends, fatal concussion would ensue. The piston of the small cylinder had work to do in moving the main cylinder valve, and pressure must be induced to enable it to do so. This was obtained by enlarging its passages, and by diminishing those of the large cylinder. The latter was the measuring cylinder, and the contracting of its passage was the cause of the small delivery of meters of this class. The ½-inch "Frost" meter delivered 43 gallons as against 100 gallons for the "Kennedy" ½-inch. If, as in a hydraulic pump, the main piston had work to do, there would be ample pressure to move the small cylinder piston, and restriction of the main passages would be unnecessary. As a meter, the principle was limited to small sizes. In fact a maker must decide to what extent he must contract his main cylinder-passage to get the reverse without injury. A few years ago the city of Boston, U.S.A., appointed a Commission to test water meters. All the meters presented were American types, except the "Frost."

(Mr. Thomas Kennedy.)

The first test was a full-bore test for a fortnight. As the supply-pipe was short, and the pressure considerable, the test was a severe one. The "Frost" went through that and the subsequent tests successfully. Nearly all the American meters broke down during the first test. Most of the meters were of the duplex type. The report gave photographs of the wrecks.

The method of reversing the piston in the "Imperial" and in the "Kennedy" meters required no diminution in the size of passages. They could be enlarged to any extent. In the former, the three pistons acted directly and continuously on the valve. In the latter the piston raised the hammer, and the valve was reversed by its fall, quite independently of the water pressure. He noted that, on page 53 the author said of his own meter:—"not a stuffing-box nor a spring among its details, and is self-lubricating." At the end of the excellent description of the "Kennedy" meter (page 47) he stated that the oiling and general seeing-to indicated some of the disadvantages attendant on its general use. This raised the question whether the working parts of a meter should be immersed in the water passing through it; or whether these parts should be protected by stuffing-boxes, and access given for oiling and seeing to these parts. A meter was an enlargement of the pipe, consequently it contained water comparatively still, which allowed it to deposit grit. In fact the water was well represented by the water scoured from a dead end, and was anything but a lubricant. The works (where these were in the water) could not be examined, nor the tightness of pistons, valves, &c., ascertained from time to time; the only indication of error was that the registration differed from the average. Then, as a rule, the meter was removed and sent to the makers, who found an extensive repair usually necessary.

Where a meter could be examined while at work, defects could be seen and rectified without removal, the works could be kept clean and oiled, and wear reduced to a minimum. This required periodic attention, the "disadvantage" could only mean the cost of this. The "Kennedy" meter was, as a rule, "seen to" by the water-works officials, consequently there were few cases where data were obtainable. To this the water works of Irvine Corporation was an exception. The district was about 10 miles long and 4 miles wide, embracing five local authorities. The meters were owned and repaired by the consumers ; and for the last fifteen years Kennedy's Meter Co. had contracted with the consumers for their maintenance. A man was sent there every three months, who examined, oiled, and saw to every meter. Non-registration was unknown. There were ninety-three meters, their capital value being £1,134. The cost of maintenance from year to year was fairly uniform ; for last year it was :—

	£	s.	d.		s.	d.	
Materials used	7	5	0	or	12	9	per cent.
Man's wages	16	3	0	or	28	6	„
Railway fares, country wages, &c.	7	13	0	or	13	6	„
					54	9	per cent.

that is, rather less than $2\frac{3}{4}$ per cent. of the capital value. The chief drawback to economical attention was the great distance between one meter and another all over the district.

As to durability of piston rollers. At a large factory in Glasgow there was fixed a group of six meters of 6 inches. In January 1896 these were fitted with a vulcanite piston, a roller, and Muirhead gear. The small-flow test has since showed that all the rollers were watertight. The quantity of water measured by each in the interim, in millions of gallons, was, in round numbers 338, 340, 357, 239, 224, 228.

Mr. WALTER G. KENT wrote that he fully endorsed the author's contention that the indiscriminate use of one type of meter for the numerous purposes for which meters were employed could only be fraught with dissatisfaction to the water-works engineer. These many purposes entailed a great variety of conditions of pressure, quality of water, and rate of flow. For all of these there was no one meter yet made which would give equally satisfactory results, but for each combination of the above conditions there was a reliable instrument available. First cost should be the last, and efficiency the first consideration of water engineers who aimed at economy in

(Mr. Walter G. Kent.)

metering. In taking, for example, one class of work out of the many purposes above referred to, there was a curious difference in the practice of different countries, although each of them was broadly working on the lines above advocated. The class of work he referred to was that of constant supplies delivered through small pipes from ½ to 1 inch diameter.

In England a large percentage of such supplies was delivered at a dribble of but two to ten gallons per hour, partly arising from the small number of people per supply—the average was about seven—and partly from the supply being usually delivered into cisterns through ball-cocks. Consequently, in England, a positive reciprocating packed piston meter was more generally employed, this being the only type of instrument that would, in the small sizes, reliably measure small flows.

On the Continent small flows were practically eliminated from consideration, as, in the large cities, which were chiefly metered, there were from seventy to eighty inhabitants per supply pipe. Therefore the minimum draft was never a small one, and it resulted that the inferential meter was adequate for the purpose.

In America also there was a comparative absence of small flows, but from a different cause. The number of people per supply was much the same as in England, but the consumption per head was several times as great. Twenty to forty gallons per head per day was as much as was taken in the large majority of English towns, but in some of the principal cities of America the consumption had touched the extraordinary figure of 200 gallons per head per day. The result of this was that positive rotary piston meters gave satisfactory results.

Turning for a moment to larger supplies, reference was made to the use of the "Uniform" rotary piston meter for the purposes of hydraulic supply. It might be of interest to engineers to know that all supplies—of which there were over 400—of the Manchester hydraulic-power system were metered by this instrument. The registration for the years ending on the 31st March for the past three years gave the following results:—

YEARS.		
1896–97 . . .	97·8	Percentage of the total quantity of water pumped, which had been registered by the meters, and paid for by the consumers.
1897–98 . . .	99·14	
1898–99 . . .	98·89	

Prior to 1896 the meters were largely of another type, and the percentage of registration was very much less. Here again was demonstrated the economy and efficiency of using the right instrument for the work to be done. A saving in first cost was no set-off against large annual loss.

There was a slight error in the first few lines of page 44 of the Paper, an old meter of the "Uniform" type, Fig. 9, having evidently been examined by the author. The lever, or tongue, was not now tipped with glass, but with a material equally hard though not brittle, and the lever was automatically adjusted to compensate for the wear.

Mr. L. S. M. MARSH, engineer to the Sheffield Corporation Water Works, wrote that the subject was one of very great interest to the water-works engineer, as an absolutely satisfactory high-pressure water meter was in his opinion still to be invented, the necessary conditions being numerous and difficult of attainment. He did not think a metered domestic supply either feasible or desirable in English towns, and the problem of the prevention of waste could be more satisfactorily controlled by means of inspection, as had been proved in Sheffield and other towns where the domestic consumption, although entirely unrestricted, was only a little over 12 gallons per head per day of the population actually supplied.

The writer had not yet been able to discover a positive meter which, taking all considerations into account, could be said to be decidedly more satisfactory than one of the best inferential type. He noticed that the author insisted on a very high standard of efficiency by which the smallest dribble should be measured. He could only hope that such might be maintained by the author's invention.

Professor HENRY J. SPOONER wrote he much regretted that the discussion was not limited to the author's meter, or, failing that, adjourned, to be concluded at the next meeting, for he had noticed that most of the speakers either confined themselves to remarks on meters in general, or referred to a particular one in which they were interested. In the author's meter, the writer considered, they had one of remarkable simplicity, one that was noticeable for the absence of some of those features which had marred the success of many of the most promising ones. Most of the well-known positive meters would work satisfactorily so long as the water was clean and free from lime crystals or other matter in suspension, or was not soft. Mr. Charles Hawksley, in his interesting remarks (page 59), pointed out that some meters, that worked very well with a hard water, were quite unsuited for use with soft water, as the rust which formed in the pipes accumulated in the meters. In this connection the writer would like to call attention to the fact that not only did the oxygen which existed in large quantities in soft water rapidly decompose the iron of the pipes and meters, but it formed carbuncles or nodules,* which retarded the flow, not so much by the reduction of the sectional area of the pipes and passages as by the alteration of the character of the surface. The effect of the presence of solid matter in meters was clearly shown by the "Imperial" meter, Fig. 25, Plate 3, which the author exhibited at the meeting, one that he assured us had been in constant use at the Nunhead meter-testing establishment of the Southwark and Vauxhall Water Works for two years and five months. The relatively small amount of deposit on this meter surprised the writer very much, as in 1890 he had a "Lacoste" meter, Fig. 26,† tested at Nunhead, by kind permission of the engineer, and after running a few days it stopped, due to the space between the diaphragm and covers being rapidly filled with muddy matter. The writer could not believe that the two meters could have been connected to the same supply. He might add that the measurement tests of the "Lacoste" meter were highly satisfactory, and he had no doubt that it could be made to give good results, if used to measure pure water only, and if it was periodically cleaned and oiled. The writer was not aware of this meter being used anywhere in this country. The author had very carefully defined the conditions under which the various types of meters were serviceable, but the writer feared that too often the most potent factor which influenced the selection of a meter was cost; hence it was that on the continent meters of the inferential type were so largely used. These meters, if made with every care and refinement, were capable of giving, within the limits defined by the author, most excellent results, but, when roughly and cheaply made, were exceedingly unsatisfactory, as the following reference to a test will tend to prove. In 1890 the writer was very much interested in water meters, and a friend of his procured for him from abroad an inferential meter of the turbine type, largely used for domestic purposes, and a "Frager" meter, Fig. 27, positive type, much used in France. These two meters were put to rough tests, but Mr. Godfrey Evans, the engineer of the Nottingham Corporation Water Works, having heard about them, and being on the look-out for a good meter, undertook to test them at his new testing station, and the following extract from Mr. Evans's report might be of interest to the members. Mr. Evans said:—"The turbine meter is not capable of registering small flows with accuracy. The turbine is of inferior design and finish, and is liable to a large amount of slip; the construction is such as to be quickly put out of order by corrosion or the adhesion of lime crystals. Generally speaking, the meter is rather roughly made up and finished, and already shows signs of wear, the oil being exhausted or escaped from the oil chamber, and the spindle having started to grind. . . . The 'Frager' double-cylinder meter appears to be capable of registering accurately any flow up to its full capacity, and there is little or no slip of water. The whole of the working parts are well made of gun-metal and are not liable to get out of order. Generally speaking, the meter is of good construction and finish, and appears to be capable of sustaining a large amount of use before showing signs of wear." In this class of meter it was of the greatest importance that the stroke should be absolute. As accurate

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* Proceedings, 1899, page 479.

† Proceedings, 1890, page 433.

(Professor Henry J. Spooner.)

measurements could only be made by positive meters whose strokes were unvarying, the slightest variation, particularly in those with large pistons and short strokes, makes an appreciable difference in their efficiency. The writer noticed that the author claimed that the stroke of his meter was definite, but he would like to ask him whether he had determined the limit of speed at which it could be run, and beyond which the stroke would be affected by the momentum of the piston and its attachments. For obvious reasons the presence of any lubricant in a meter was objectionable where pure or drinking water was being passed; so, bearing in mind the splendid wearing qualities of lignum vitæ when lubricated with water, to which Professor Unwin had called attention (page 60), it seemed to the writer that it would be possible, by some slight alteration in the details, for the author to make his meter almost independent of a lubricant. Bearing in mind the trouble of periodically cleaning out the ports and passages, it might be worth while considering whether the body A, Plate 1, could not be advantageously fitted with a removable cover at the bottom. This of course would add slightly to the cost, which would be against it for most purposes, but it would, on the other hand, somewhat simplify the casting. In conclusion, he very heartily congratulated the author on his production of a meter which had evidently been thought out with great care, and one that, so far, had given such eminently satisfactory results. The fewness of its working parts, its simplicity, the working parts being easily get-at-able, and the fact that it could be worked by such a small head of water, were factors, the value of which could not be overrated, and he trusted that he would be able to emulate the public spirit of other inventors, and either lend or present a working model of it to the South Kensington Museum, where the nucleus of a very fine collection of working water-meters is on view.

Mr. SCHÖNHEYDER wrote that, referring to the cogent observations of Mr. Charles Hawksley (page 59), he recognised at the outset of his investigations and experiments that rust deposit, lime crystals in suspension, and similar evils were inevitable (in a greater or less degree) in all water services, and that in course of time these impurities must unfavourably affect the working of a meter. He concluded therefore that any appliance capable of withstanding these onerous conditions must be so constructed that it could be taken apart, cleansed, and re-instated on the spot by unskilled labour, and it was to the production of a meter capable of being so dealt with that in a great measure his attention was directed. By having the dirt box inside the casing the operation of cleansing was facilitated, as both could be dealt with simultaneously, and the meter kept practically up to the standard of a new one. Owing to the overlapping motion of the valve and the speed with which the water passed through the ports, the valve and seating were not appreciably affected by the presence of sand, grit, or lime; and even in cases where meters had been found full of deposit the faces had been bright as mirrors and perfectly tight. When the difficulties mentioned above were unusually pronounced, the author recommended vulcanite cylinders in lieu of gun-metal ones.

Mr. Philip Bright observed (page 62) that if inferential meters were used "small enough" they could be made to register "very small flows indeed"—a statement carrying its own limitation; and while he added that their capacity at full flow was only about 120 or 140 gallons an hour he did not mention the pressure which would be necessary to force this quantity of water through them,—a vital consideration, which would have shown that it was impracticable to reduce the capacity of a meter to its smallest limits to secure accuracy. The impossibility of using small inferential meters in Berlin for domestic supplies was alluded to by Mr. Morris (page 73). Referring to inferential meters Mr. Bright added that "meters were made and were at work which would register 2 or 2½ gallons an hour perfectly accurately." The author quite accepted this statement, but could only assume it had reference to tests made with a new meter, which should be easily attainable, and not to results taken in actual and prolonged work.

Inferential meters of the "best class obtainable" after a number of years' trial in a town, where all house supplies were measured,

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proved so unsatisfactory that not only had they been superseded by "Imperial" meters, but it had been found an economy to discard those in actual use and to replace them by the positive type.

In further reply to Mr. W. B. Bryan (page 64), the author was glad to note his opinion that the metering of house supplies "would save capital by obviating the necessity for going further afield for water as early as would otherwise be the case"; but he regretted to learn that in the opinion of so competent an authority "the cost of meters and meter-rent in some districts would be very prohibitive." This was not the conclusion to which the author's figures had led him, whether the question was considered from the position of a waterworks shareholder, consumer, or ratepayer.

The meter mentioned by Mr. Isaac Smith (page 65) was apparently a new edition of the Siemens inferential meter; in the absence of actual working results it was impossible to say whether it would prove better or worse than those now in use.

Mr. Edward B. Ellington had compared the size and delivery of the "Imperial" meter with that of a "Kent" (page 69), to the disadvantage of the former. There was evidently some confusion on this point as the two were not capable of comparison; Messrs. Kent's "Absolute" meter, and not their "Uniform" meter, should have been selected for this purpose.

The information supplied to Mr. George Cochrane (page 69) of a registration of 98 per cent. of pumped water on the Manchester hydraulic system did not apparently coincide with his own experience, as he said, "such a percentage could not be claimed in London," and it was not in accordance with the statement of Mr. Ellington who, speaking of the same meter (page 68), said, "it would not register very small flows except for a very short time after being put to work."

The author thought that the meter described by Mr. Joseph Bernays (page 77) was most ingenious in construction, but he regretted to say he had not had an opportunity of investigating the results obtained in actual work, and therefore was unable to form an opinion as to its merits.

Mr. Harry Francis in his communication (page 78) pointed out a fault in the "Imperial" meter "that the first cost was great compared with other meters." If a comparison were made between the cost price of positive meters, these would be found to be practically the same, but they were of course more costly than those of the volume or inferential types. The author was not aware until he saw Mr. Francis's communication that he had been using his meter so long or with what results, and learnt with satisfaction that he had found it efficient for measuring dribbling supplies.

Mr. Fred Hunter's loyalty to his old friends the "Kennedy" and "Siemens" meters was much to be admired (page 78). As, however, they were not in the same category, the author did not understand how one of them could be classed as above or below the other in efficiency.

The remarks of Mr. Thomas Kennedy (page 79) on the "Frost" meter and the reasons for the great difference in the size of its two cylinders, the author regretted he was unable to follow. He had seen many of these meters at work, and had listened to the "thumping" at each reversal of the main piston; he had also been witness to several breakdowns due to this cause. It would therefore appear that if the theory of construction were correct, it was not supported in practice. Experience with the "Imperial" meter did not bear out Mr. Kennedy's contention that the water in a meter was not a good lubricant, or that the working parts being immersed in water could not be periodically examined, and consequently were allowed to run until expensive repairs were necessary. On the contrary, the greatest advantages accrued from all the parts of the meter being easily exposed as well as from the absence of stuffing-boxes and the like. The small cost of upkeep of the "Kennedy" meters of the Irvine Corporation was certainly very satisfactory (page 81).

The author was pleased to find himself in accord with the main contentions of Mr. Walter G. Kent (page 81), but he differed from him as to inferential meters on the Continent and volume meters in America proving adequate for the duty assigned to them. Positive meters were demanded in some of the most important continental

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cities, and the American technical journals bore witness to the fact that engineers were increasingly dissatisfied with volume meters, because they failed to register small flows.

The "Uniform" meters in use on the Manchester hydraulic system, quoted as giving an efficiency of 98 per cent. (page 83), though now packed at the edge of the piston-blocks with a self-adjusting lever made from durable material, were certainly not packed on the flat sides of the piston-blocks; how therefore they could register so large a percentage of the flow through them was incomprehensible.

The author thought that Mr. Marsh was probably right in his opinion (page 83) that an "absolutely satisfactory" meter had still to be invented; perfection was by no means easily obtained, but the author suggested that if Mr. Marsh would place one of the positive meters described in the Paper tandem with one of the "best type" inferential on a dribbling supply, he would probably make the discovery which up to the present time had eluded him. It was a matter of common knowledge that not one dribbling supply in ten, charged on the reading of an inferential meter, was paid for to the extent of two-thirds the value of the water consumed.

Professor Spooner having investigated the subject of water meters on somewhat different lines to the author, his comments (page 84) on the Paper were of exceptional value. The main point raised in his communication (page 86) was whether the inventor "had determined the limit of speed at which it could be run and beyond which the stroke would be affected by the momentum of the piston and its attachments." The author had made frequent and exhaustive trials to discover if such a limit as that could be found, and the appended tests from an independent source would probably be conclusive evidence that the danger indicated did not exist.

The $\frac{3}{4}$-inch meter has $3\frac{3}{4}$-inch cylinders, the pistons have a stroke of $1\frac{7}{8}$ inches and are very light, and at 100 revolutions per minute the meter delivers about 1,350 gallons per hour, but in practice it is very seldom run at this speed.

In regard to the meter lent by the Southwark and Vauxhall Co. (page 84), and attested by them as to length of service, registration, and high and medium tests, the author did not know on what particular service it had been placed; and of course there was a great difference in the purity of water in different districts, according to the greater or less demand on the mains. It was however by no means an unfair specimen of the general condition of meters after two or three years' use. An examination of the "Imperial" meter will show that all the ports and passages are accessible by removing the valve-seating; no further provision therefore is necessary for cleaning purposes.

TABLE 3.—*Tests of ¾-inch "Imperial" Meter No.* 3683, *after having been seven months in use, when it worked slowly with* 5 *ft.* 7 *ins. head, and was found correct.*

Outlet.	Litres per hour.	Gallons per hour.	Per cent. error.	
			Slow.	Fast.
¾ inch	6,666	1,468	–	–
¾ inch cock	5,000	1,100	–	0·5
½ inch	3,428	754	–	0·2
10 m/m	2,927	644	–	0·2
8 m/m	2,308	508	–	0·5
7 m/m	2,069	455	–	0·3
6 m/m	1,666	367	–	0·5
5 m/m	1,200	264	–	0·7
4 m/m	857	189	–	1·3
3 m/m	400	88	–	–
2 m/m	200	44	–	–
1 m/m	80	18	–	–
0·7 m/m	54	12	–	2·0
0·5 m/m	30	6·6	–	–

Having been asked to state what determined the direction of movement of the meter, the author wished to say that this was governed by the position of the ports in the valve and seating in relation to that of the cylinders. Thus, looking at Fig. 22, Plate 2, the port D_1 on the right-hand side of the seating communicates with

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the cylinder B_1 in the front; therefore when the valve is leaning over, say to the right as in Fig. 19, Plate 1, the bottom of the said cylinder B_1 will communicate with the discharge, and its piston must therefore descend, while one or both of the two other pistons will rise, and as this action is repeated in succession for each cylinder, the direction of movement is determined. It must be understood that Fig. 19 is not a correct section on a straight line, looking in plan, as each cylinder is at a right angle with its port. The form of the passages necessitated by this relative position is shown by the right-hand section, Fig. 20.

An excellent Paper, dealing fully with the subject of American water meters was read and discussed before the American Society of Civil Engineers by Mr. John W. Hill, of Wyoming, on 1st February 1899, when the assertion as to the inability of the volume meter to register small flows and the widespread desire for a better meter in the United States were fully borne out by the speakers.

The Institution of Mechanical Engineers.

PROCEEDINGS.

FEBRUARY 1900.

The FEBRUARY MEETING was held at the Institution on Thursday, 22nd February 1900, at Eight o'clock p.m. Owing to the unavoidable absence of the President, Sir William H. White, K.C.B., the chair was taken by J. HARTLEY WICKSTEED, Esq., Vice-President.

The Minutes of the previous Meeting were read, approved, and signed by the Chairman.

The CHAIRMAN announced that, in consequence of the election of Mr. John A. F. Aspinall as a Vice-President, the vacancy thereby occurring had been filled by the Council, who had appointed Mr. ARTHUR TANNETT WALKER, of Leeds, as a Member of Council for the present year; and that agreeably with the Articles of Association, he would retire at the next Annual General Meeting, and would be eligible for re-election.

TRANSFERENCES.

The CHAIRMAN announced that the following three Transferences had been made by the Council:—

Associate Members to Members.

NEWTON, SAMUEL BARTON, ...	Derby.
PILLING, HENRY, ...	Manchester.

Graduate to Member.

TAYLOR, JOSEPH, ...	Manchester.

Two Papers were read and partly discussed:—

"Improvements in the Longworth Power-Hammer"; by Mr. Ernest Samuelson, *Member*, of Banbury.

"Portable Pneumatic Tools"; by Mr. Ewart C. Amos, *Member*, of London.

Before the Discussion was adjourned, the Chairman said that there was an almost inexhaustible store of discussion to be drawn upon. He thought it was now the right time to express on behalf of the members the thanks of the Institution to the authors of the Papers. The Papers, he was sure, were appreciated by the members; they were both good, and the Institution was much indebted to the authors for them. On behalf of the members he now conveyed to them formally the thanks of the Institution.

The Meeting terminated at Half-past Nine o'clock. The attendance was 124 Members and 104 Visitors.

The Institution of Mechanical Engineers.

PROCEEDINGS.

March 1900.

The March Meeting was held at the Institution on Thursday, 22nd March 1900, at Eight o'clock p.m. The chair was taken by J. Hartley Wicksteed, Esq., Vice-President, in the absence of the President, Sir William H. White, K.C.B.

A letter from the President was read expressing his great regret that the state of his health did not permit him to attend the Meeting, and containing his recommendations on several important matters, including the reception of American visitors at the Summer Meeting. He also stated that he was ready to place himself unreservedly in the hands of the Council, and to fall in with what arrangement was most desirable in the interests of the Institution.

The Chairman said that the Council had unanimously come to the conclusion to retain Sir William White's Presidency over the Institution, whether he was able to attend the meetings or not. They had no idea whatever of appointing a new President until Sir William's term had expired.

The Minutes of the previous Meeting were read, approved, and signed by the Chairman.

The Chairman announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following fifty-one candidates were found to be duly elected :—

MEMBERS.

Aitken, Hugh Wallace,	Glasgow.
Chambers, Thomas Hall Winsley,	Middlesbrough.
Collinson, Arthur,	Gateshead.
Cooper, William,	Edinburgh.
Cope, Harry Charles,	Keighley.
Denham, John,	Cape Town.
Dews, Frank,	Birmingham.
Dow, James William,	Oswestry.
Fujii, Terugoro,	London.
Grant, Lewis,	Kirkcaldy.
Mansell, William Robert,	Wellington, Salop.
Parkinson, Joseph,	Shipley, Yorks.
Quirk, William Montague Harley,	Fremantle, W. Australia.
Shaw, Percy Charles William,	Sydney.
Sparkes, Samuel Hurford,	Wellington, Somerset.
Watson, George,	Leeds.

ASSOCIATE MEMBERS.

Adams, Albert Edward,	Chippenham, Wilts.
Aitken, Thomas Martin,	Erith.
Albrecht, John August,	Glasgow.
Bishop, Charles Herbert,	Liverpool.
Brooks, Harry Gordon,	London.
Clarke, Leigh Theophilus,	Woodford, Northants.
Ellison, John,	Bradford, Yorks.
Enock, Arthur Guy,	Pretoria.
Godson, Edward Harold,	Crewe.
Hodgson, George Henry,	Sydney.
Humphrey-Moore, Montague George A.,	London.
Keatinge, Sherbrooke Augustus John,	Lucknow.
Locket, Athol,	Dibrugarh, Assam.
Marshall, Thomas,	Woolwich.
Moore, George Edward,	Ipswich.
Morton, Duncan Anderson,	Errol, Perthshire.

Smith, John Bucknall,	London.
Warden-Stevens, Frederic J.,	London.
Williams, Arthur,	Mexico.
Wood, William Howorth,	Johannesburg.
Wright, Ernest,	London.

ASSOCIATES.

Feather, Robert,	Bradford, Yorks.
Goodrich, Walter Francis,	London.

GRADUATES.

Attock, Frederick William,	Horwich.
Boreham, George Henry,	London.
Bott, Walter Stanley,	London.
Chubb, Harry Emory,	Leeds.
Creswell, Francis Samuel,	London.
Davies, Edward Ayerst,	London.
Hopkinson, Allen Haigh,	Huddersfield.
Ingate, George James Arthur,	Cardiff.
Mackessack, Harry,	Grantham.
Plaister, William Edward,	London.
Richards, James Garfield,	London.
Winch, Apsley Brooke,	London.

Transferences.

The Chairman announced that the following five Transferences had been made by the Council:—

Associate Members to Members.

Back, Arthur Charles Lemprière,	Plymouth.
Johnson, Andrew,	Glasgow.
Roylance, Arthur Herbert,	Manchester.
Scotter, Robert Herbert,	Southport.

Graduate to Associate Member.

Ridley, James Cartmell, Jun.,	Newcastle-on-Tyne.

The Adjourned Discussion was resumed and concluded on the two Papers read at the last Meeting:—

"Improvements in the Longworth Power-Hammer"; by Mr. ERNEST SAMUELSON, *Member*, of Banbury.

"Portable Pneumatic Tools"; by Mr. EWART C. AMOS, *Member*, of London.

The Reading and Discussion of Mr. Bryan Donkin's Paper on an "Improved Glass Revealer" was postponed.

The Meeting terminated at a Quarter to Ten o'clock. The attendance was 136 Members and 121 Visitors.

IMPROVEMENTS IN THE LONGWORTH POWER-HAMMER.

By Mr. ERNEST SAMUELSON, *Member*, of Banbury.

Whilst economy in power is engrossing the attention of all who are engaged in the manufacturing interests in this and other countries, and the tendency is to concentrate steam power in one spot, and convey its energy either by means of electrical power or by shafting and belts, or by a combination of both, to the tool, we are brought to the consideration of, amongst other things, the advantage in the use of Power-Hammers in place of Steam-Hammers ; and as this subject has not been before the members of this Institution since 1882, when Mr. D. Longworth read a Paper* describing a hammer in which the blow was rendered variable by means of a movable fulcrum, the author has thought that a short description of some further improvements upon this design of hammer may be of interest to the members.

In 1891 the author's attention was directed to Mr. Longworth's patent of the previous year, and, being struck with the advantages of the principle upon which he had improved his hammer, entered into an arrangement with him for the manufacture of the same, and the various drawings here presented serve to illustrate these improvements, and the principle upon which the hammers are now built. They form a distinct departure from all previous modes of construction, as instead of varying the intensity of the blow by means of a movable fulcrum or frictional brake upon some of the moving parts of the hammer, it is regulated by means of a cushion of air rendered variable in volume under the piston in a controlling cylinder in a simple manner, by means of an air-valve under the control of the attendant.

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* Proceedings, 1882, page 204.

Fig. 1.

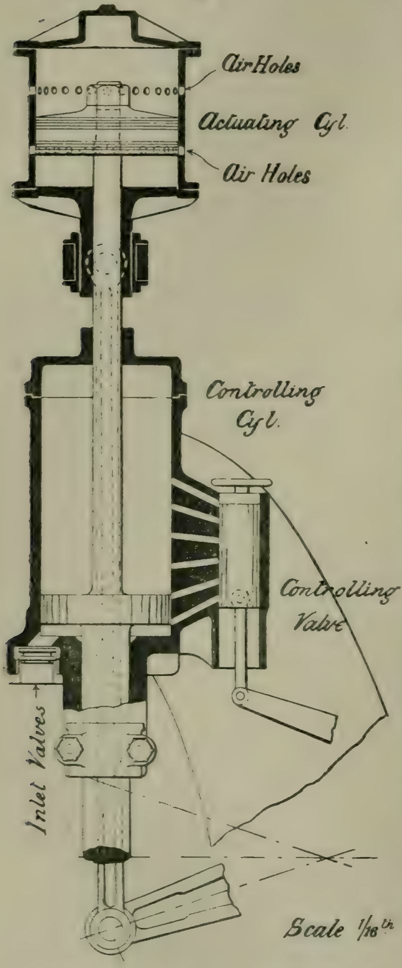

Fig. 1 is a sectional view which serves to illustrate the principle upon which the hammer is built. It will be seen that the hammer consists of the usual piston, piston-rod, and tup, but the piston-rod is prolonged upwards, and carries a supplementary or second piston working in a second cylinder. The lower cylinder merely acts as a "controlling" cylinder for regulating the intensity of the blow, which is effected by means of a series of air-ports communicating with the lower cylinder and the outside atmosphere, which ports can be opened or closed one or more at a time by a simple cylindrical plug valve, under the control of the attendant, by means of a hand or foot-lever, Fig. 2, Plate 5. The top piston works in a second or "actuating" cylinder freely in a vertical line, and a double series of air-holes communicating freely with the atmosphere is drilled round this cylinder to regulate the cushion of air in the same, according to the nature of the work to be done under the hammer, and to prevent the piston striking the covers; this cushion also assists in intensifying the blow, and in lifting the tup on its upward stroke. The upper or "actuating" cylinder is connected by means of a crosshead, with two side links, to one end of a rocking lever working upon a fixed fulcrum, whilst the other end of this rocking lever is connected to a crank by a connecting-rod.

Thus, when the crank is put in motion, the rocking lever raises the side links, and with them the upper cylinder, until the top piston cuts off the air at the bottom row of holes in same, and, this air becoming compressed by the cylinder still continuing to rise, eventually lifts the top piston with it, and thereby the piston-rod and tup. Upon the crank passing the bottom of its stroke, the top cylinder gains upon the falling piston and tup until it closes the communication of the air through the top row of holes, after which this air is compressed, and the motion of the falling piston and tup is thereby accelerated. If now the lower cylinder is in free communication with the atmosphere through its bottom air-ports, the tup will fall to its lowest point, viz., the face of the anvil, and the full force of the blow will be struck; but if all these air-ports are closed, the lower piston will compress the air in the bottom of the controlling cylinder, until that pressure is sufficient to sustain the falling weight, and the tup will be prevented from striking the anvil.

Small self-acting air-valves in the bottom cylinder allow air to be drawn in by the lower piston on its upward stroke when necessary to restore atmospheric equilibrium; these however remain at rest when the lower cylinder has free atmospheric communication through the lower ports. The top of the lower cylinder remains in free communication with the atmosphere at all times. The cylindrical air-valve is under the control of the attendant by means of a suitable system of hand or foot-levers, Plates 5–8, and is kept in its normal position covering the whole of the air-ports to the lower cylinder by means of a spring, as shown on Figs. 3 and 4, Plate 6; and when the hammer is started, the piston works upon an air-cushion, as explained, and the work can be readily introduced upon the anvil. By opening one or more of these air-ports, the air-cushion in the lower cylinder is regulated and the force of the blow controlled, and by rapidly opening and closing them again, the attendant can deliver single blows upon his work — this of course being contingent upon the thickness or height of the iron being less than the clearance between the tup and anvil when the hammer is running upon its greatest air-cushion, which can be allowed for in the designing of the hammer to suit particular work. The speed and stroke of the hammer can be varied to suit different classes of work; thus, for riveting or cutlers' work, Plate 7, a quick speed and short stroke can be maintained, whilst for general forging or stamping, Plates 6 and 8, a long stroke and moderate speed is obtainable, which enables the attendant to move or handle his heat on the anvil.

Owing to the comparative length of the side links, the versed sine of the arc through which the end of the rocking lever moves affects but slightly the true vertical motion of the top cylinder, and the tendency to wear sideways is reduced practically to a negligible quantity by being guided in a long neck or gland on the top portion of the piston rod in the earlier design. The lower or main piston-rod is similarly guided in another long neck on the lower cylinder, and the tup is placed between side guides where a hammer of this type is required, as in Fig. 13, Plate 8. In order to reduce the total height and to better guide the top cylinder, the author has more recently brought this cylinder down to work inside the controlling cylinder, Plate 5, making the top cover serve as a guide, thus relieving the piston-rod of that function, the links being journalled on pins formed on the top cylinder cover, see Figs. 2, 3, and 4.

In the earlier design the wear of the tools was provided for by the cross-head being adjustable upon the top cylinder gland, see Fig. 1 (page 100), whilst in the later design, the connecting rod to the crank is made so that it can readily be lengthened or shortened as shown in Plate 5, the proper position of the top cylinder relative to the anvil being, when the faces of the tool are touching each other, and the front end of the rocking lever is at the lowest point of its stroke, the bottom of the piston in the top air-cylinder should just cut off or close the bottom row of holes in same. The working cylinder being so far removed from the work upon the anvil, no danger is incurred from grit or heat affecting it.

Fig. 5, Plate 6, illustrates the acceleration of the actuating cylinder due to the position of the crank and rocking lever in a 3-cwt. single standard hammer. The uniform speed of the crank being 5·88 feet per second, the speed of the rocking lever, and with it the actuating cylinder and tup, is accelerated on the down stroke to about 9·5 feet per second at mid stroke.

Figs. 6 and 7, Plate 7, show a different form of drive adopted for the smaller sizes of hammer, such as for riveting work, the movement being obtained by means of a crank and a slide block on the top of the cylinder cover; but this form is not recommended for the larger sizes and heavier work.

Figs. 8 and 9, Plate 7, show a hammer designed for planishing where the blow is regulated by means of a movable fulcrum. This hammer is fitted with a rocking lever similar to Longworth's earlier arrangement (Proceedings 1882, Plates 28 and 29), and a ready means of regulating the blow when the hammer is at rest is found to suffice, instead of adding the additional parts of the controlling cylinder, &c.; because in this class of work, when once the strength of the blow is determined upon, it remains constant, and can be stopped by means of belt shifting-gear. The controlling cylinder however can be fitted to this class of hammer if desired, when the movable fulcrum is dispensed with, and a rocking lever of similar type to the other hammers is used.

Figs. 10 and 11, Plate 8, illustrate a hammer specially designed for welding boiler flues, the flues being carried on any suitable saddle, such as are used in boiler shops; and a special advantage is obtained in the use of such a hammer in this class of work, because of the uniformity in the number of blows per minute. Thus when the first few heavy blows are given, the lighter ones which follow to finish the work are delivered at the same speed, and the fullest advantage is taken of the heat, whereas in a steam-hammer when the lighter blows are delivered a reduction ensues in the number per minute.

Figs. 12 and 13, Plate 8, illustrate two further types of framing for general smiths' work.

The power required to drive the hammer is proportionate to the work being obtained from same, for when the hammer is running upon its full cushion of air in the controlling cylinder, the compressed air assists in raising the tup on its upward stroke, and a minimum power is required. This increases as the blow is intensified until no cushion exists, and the full blow is given. Fig. 14, Plate 9, shows the power absorbed by a 3-cwt. hammer when running light, and when delivering the fullest blow; these were taken from a steam-engine connected through a countershaft to the hammer, the actual power absorbed being 3·1 and 8·7 I.H.P. respectively, after deducting the friction of the engine, shafting, &c. Fig. 15 shows cards taken from the top and bottom of the actuating cylinder of the same 3-cwt. hammer, and from the controlling cylinder when one air-port is open down to the position where all are open, and the hammer is giving its fullest blow.

Fig. 16 represents cards taken from a 4-cwt. steam-hammer, having 8-inch cylinder with 16 inches stroke, which shows the wasteful power expended in tools of this class, for whilst about 64 lbs. of water are required per I.H.P. per hour to work this hammer from the calculations as below, a fairly economical engine should not use more than about, say, 20 lbs., and it is in this respect that the advantage of a Power over a Steam-Hammer is most evident.

Water consumption of 4-cwt. steam-hammer as taken from cards on Fig. 16, the average pressure at end of stroke being 15 lbs. above atmosphere:—

Cylinder, 8 inches diameter × 16 inches stroke.

Number of blows per minute, 120.

Thus $50 \times 16 \times 120 \times 2 = 192{,}000$ cubic inches, or the volume of steam used per minute.

Specific volume of steam at 30 lbs. absolute = 838.

Thus $\frac{192{,}000}{838} = 229$, or the cubic inches of water used per minute,

and $229 \times 0{\cdot}036 \times 60 = 494$, or the lbs. of water per hour.

The I.H.P. being 10, as taken from the cards, the water used per I.H.P. per hour = 49·4, to which must be added a liberal allowance for condensation in the cylinder and steam-pipes, say 30 per cent., which would make the consumption of water = 64 lbs. per I.H.P. per hour.

The Author exhibited the 3-cwt. Power-Hammer shown on Plate 4, and also two specimens of mild steel discs, each of which had been flattened at one heat under a similar hammer, from a cylinder 2 inches diameter by 2 inches long; they now roughly measured 6 inches diameter by $\frac{1}{8}$ inch thick. A piece of high class tool steel was shown after being drawn down under the same hammer; it measured 2 feet 6 inches long by $\frac{3}{4}$ inch square, its original size having been $5\frac{1}{2}$ inches long by $1\frac{3}{4}$ inches square. A piece of cast steel was also shown drawn down from $1\frac{3}{4}$ inches square under a 4-cwt. steam-hammer in one heat, the original length having been $5\frac{1}{2}$ inches now measured 40 inches long by $\frac{5}{8}$ inch square. The 1-lb. riveting hammer shown on Plate 4 was also exhibited, together with a sample of cycle roller-chain riveted by the Albert Eadie Chain Co., of Redditch, with this hammer, which was riveting 450 feet per working day of 10 hours, as against 100 to 112 feet formerly by hand, the rivets being $\frac{1}{8}$-inch and $\frac{1}{2}$-inch pitch.

The Paper is illustrated by the Figure in the text and by Plates 4 to 9, which are reproduced from the author's drawings and from the machinery shown at the Meeting.

Discussion on 22nd February.

The CHAIRMAN asked Mr. Samuelson if he would like to add any remarks before the discussion commenced.

Mr. SAMUELSON thought it would be better to let members raise any points in the course of discussion, to which he could then reply. The section, Plate 5, showed plainly the principle on which the hammer was built, and was simple and intelligible, and therefore he would not waste the time of the meeting at that moment.

The CHAIRMAN said that he hoped that any of the members present, who had had practical experience with the use of the machines, would take part in the discussion. If they had any criticisms to make, or any admiration to express for the tools, it would

(The Chairman.)

be pleasant to the author of the Paper to hear any appreciative remarks. If there were any defects to find in them arising from actual practice, it would of course be more valuable to the members to hear those observations than merely theoretical criticisms on the mechanism. There might also be present those who had tried other makes of machines of power-hammers and pneumatic tools, and they might be able to say something about the conditions under which the one make or the other make could be applied most favourably. In addition to that he thought it would be quite fair for anyone who had had experience of a power-hammer and of steam-hammers to give an opinion as to where the advantages of a steam-hammer came in, because the Paper had challenged that by alluding to steam-hammers, and to the consumption of steam used in them, as well as to other points of difference between the steam-hammer and the power-hammer. Similarly to that, it would be quite suitable for anyone who had had experience in using electric drills, as well as pneumatic drills, to furnish some information about them. He did not suggest bringing in those outside comparisons from a purely theoretical point of view, but it would be extremely valuable if anyone had used both systems to hear the results of his preference.

The SECRETARY called attention to three diagrams on the wall that were not referred to in the Paper. Two of them illustrated Mr. Waterhouse's compressed-air forge-hammer, described in a Paper read by Mr. Charles Beyer in 1858.* The other drawing was by Mr. David Joy of a power-hammer with an air cylinder, Fig. 17, Plate 10. The hammer, of which a great number had been made, was used for forging horse-shoe nails. The date of the drawing was 1871.

Mr. E. J. CHAMBERS said he had had some little experience in the use of the Longworth power-hammer. In a weak moment, about five years ago, he introduced himself to Mr. Samuelson as one who wanted a Longworth power-hammer. For a long time he had been convinced that when a School-Board education had been given to most working people, there would not be many of them willing to work an oliver. He would say that oliver work, puddling, and mining, were very much on a par as regarded hard labour, and that no educated man would follow any of those occupations. Seeing as he did that the time would soon come when men would absolutely refuse to work olivers, he set to work to see how a machine could be made that would help to do away with that work, and after looking at other power-hammers he decided to give the Longworth a trial. He had had many an anxious night, not exactly a sleepless one, and many a worrying day, over that weak moment. Mr. Samuelson was quite right in saying that he, the speaker, had given repeated orders for these hammers. He had the first power-hammer five years ago; where it was now he did not know. It was a wreck. But thanks to Mr. Samuelson's assistance, he had some more built embodying suggestions that Mr. Samuelson was good enough to accept from him; and after working these, other suggestions were carried out, and a good deal of time spent in re-designing a special hammer, with the result that a very much better tool was obtained than the first. Mr. Samuelson would correct him if he was wrong, but he considered that a better tool was obtained, although not perfectly satisfactory to himself. It was a hammer that he would not give up, but he thought it was necessary to caution any of the members who wished to follow in his wake and use that hammer, that they must make up their minds to several things. First of all, the men it was desired to help by removing their hard labour would be the first to go dead against its adoption, and might probably arrange that the hammer should not do its work satisfactorily. The next thing was that partners, or foremen, or managers, would all say, "I told you so," when the hammer first broke. Then would come the real difficulties of the machine, the trying to make it do the special work. That had been his greatest difficulty. He might say that at the present moment he had no trouble with his men with the hammers, and he had fourteen of them at work. They were making, he thought, about 500,000 strokes a week each, that was 120 strokes a minute each. One great advantage about the hammers, which was

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* Proceedings 1858, page 118.

(Mr. E. J. Chambers.)

not generally met with in steam-hammers, was that they only required one head to work them, and that need not be a very high-class head. It wanted a cool head, but it did not require more than one head. A couple of heating-boys were necessary. Some of the members would probably start with one boy, and if they listened to their men they would find that was all the hammer could do with. But if they made up their minds to have another boy, they would find a couple of boys could heat work nearly as fast as the hammer could forge it. But the difficulty he had had with the hammer was its want of adjustments. He was always begging Mr. Samuelson to put in some more adjustments, and Mr. Samuelson knew as well as he did the difficulty of those adjustments when the hammer was making 120 strokes a minute week in and week out—say 120 strokes, and perhaps half that number of blows, because a stroke and a blow were not the same thing with the power-hammer. It might be running light, and a certain amount of time must be given to getting the work fixed, but the number of blows was very great, and when the vibration was taken into consideration, first of all in the tools and then in the hammer-block and in the working parts of the machinery, it could be quite understood why he wanted adjustments. Mr. Samuelson had certainly made very great improvements. The upper cylinder had been brought down below. He had had one break off short and fall within about six inches of a man. As fast as he could he was going to alter his old hammers, of which he had half a dozen, into new. What he wanted Mr. Samuelson to do—and he had no doubt he had come there prepared to state he was able to do it—was to make more adjustments in the hammer, and to cure those defects. It could be well understood that a crank-shaft going at that speed, after about a month's wear, if it was working in bushes, would be subject to a great deal of play, and from the moment it began to play the hammer was knocking itself to pieces. It was those points that were so necessary to be seen to in a tool of that kind. This hammer was subjected to a much greater strain, to his mind, considering its form, than the steam-hammer. The steam-hammer had practically only its vertical stresses, whereas in the power-hammer there was the rocking-bar and the crank-shaft, which were subjected to an immense amount of vibration, and those parts required to be improved, so that they could be adjusted and maintain their alignment. He hoped Mr. Samuelson would increase the mass in his further improvement of the Longworth power-hammer. He had no doubt that Mr. Samuelson would say that he (the speaker) wanted a 1 cwt. hammer to do a 5 cwt. work.

Mr. Samuelson.—And at a 1 cwt. price?

Mr. Chambers.—That might be; but it was for Mr. Samuelson to make a tool which should have all it ought to have in it, and then he could say, "You can have this tool if you like at this price; if you would like to have one without these improvements you can have one at half the price." He might mention that he used the hammers for making spindles of various sizes, for the same purpose for which the old Ryder forging machines were used with oliver work, not bolt work. It might be applicable to bolt work, but for general forging of round light spindles he believed the tool was one of the best that could be used.

Mr. J. A. Boorman said he had had some little experience with pneumatic-hammers, but not so much with the power-hammer which had been described in the Paper. He had, however, much experience with another power-hammer, and had found out several peculiarities which it had in common with other power-hammers. In the first place he thought that it was quite a mistake to assume that the power-hammer was going to displace the steam-hammer altogether. Both hammers had their uses. The use of the power-hammer, to his mind, came in more especially for swaging, planishing, and forging between dies. He had not yet seen a power-hammer which could strike a single blow satisfactorily. In the first Paper Mr. Samuelson claimed that that could be done with the Longworth power-hammer, but he thought that even with that hammer it could not be done in a very satisfactory manner. To strike a single blow of a light or heavy nature was of great

(Mr. J. A. Boorman.)

importance in certain classes of work, and he did not think that any power-hammer at the present time was sufficiently sensitive to strike a single blow which could be said to be under absolute control. With regard to the economy of pneumatic-hammers, he did not doubt for one moment that they were very much more economical than steam-hammers. That had been proved over and over again. The same arguments which were used in the Paper with regard to the Longworth power-hammer equally applied to other power-hammers in that respect. But there was one point about the pneumatic-hammer where it differed very considerably from the steam-hammer, namely, that a single blow could not be struck, and the tup could not be allowed to come down on the work and pressure put upon it as could be done with the steam-hammer, when bending anything over the anvil block. But in a well constructed pneumatic-hammer, very light blows could be dealt, and gradually increased to the maximum blow desired to be struck. In some power-hammers the blows could be immediately stopped without the necessity of shifting the belt by simply taking the power off with the foot or the hand-lever. He might say he had not seen the Paper before that evening, and had not intended to take part in the discussion until unexpectedly called upon to do so from the chair, and there were some points in it which he should like to think a little more about.

Mr. William Reavell said that some little time ago he was contemplating putting down a hammer in his works, not a power-hammer of the Longworth type, but a steam-hammer of the ordinary type, worked by compressed air instead of by steam. His idea was that the principal losses with the steam-hammers were due to condensation. Perhaps Mr. Samuelson would be good enough to say whether he had applied to an ordinary hammer compressed air instead of steam.

Mr. Samuelson said that he did not claim for power-hammers an exclusive place in workshops. They were useful up to certain sizes, but not beyond, and he should not like the members to go away with the idea that he thought a five-ton power-hammer was going to take the place of a steam-hammer.

Mr. E. J. CHAMBERS said a power-hammer would strike a single blow. Half a dozen strokes could be made in the air and then one down upon the anvil. The power of the blow could be varied by the pressure of the foot. It could certainly strike a single blow, but not so easily as with a steam-hammer.

Discussion on 22nd March.

The CHAIRMAN, to put the meeting *au fait* with the nature of the discussion at the preceding meeting, referred to the Longworth Power-Hammer. He pointed out that it was driven by a belt, and that the shaft which drove the belt could be electrically driven, or driven in any other way, so that in that sense it could be an electrically-driven hammer. The crank at the back rocked a rocking bar which took hold of the two long connecting-rods, but was not coupled directly with the ram of the tup. It took hold of an air-cylinder which contained a piston with a certain amount of play between the rings of perforation, so that there was lost motion between the cylinder and the ram. That, of course, was necessary to allow for the tup coming in contact with the thicker piece and avoiding breakage of the mechanism, and probably also it improved the blow by the elastic start which the air at the top of the cylinder gave it. At the lower part of the ram, as would be seen from the diagram, there was another piston working up and down in a fixed cylinder which had a number of air-ports in it, which could be all closed, or any number left open. If the whole of them were closed, the compression of air in the bottom cylinder arrested or tended to arrest the motion of the tup, and prevented it striking down so close to the anvil, or striking an unnecessarily strong blow. The discussion was opened a month ago, when Mr.

(The Chairman.)

Chambers had stated that he had used a great number of these hammers in place of olivers, and had used them with very great advantage (page 107). They would work very rapidly, up to 180 blows a minute. Mr. Chambers also suggested that adjustment to the joints would be a very good thing, because they were worked very hard, and got a certain amount of play. He, the Chairman, thought there was scope there for good mechanism, but if these adjustments were not very carefully designed he had no doubt the remedy would be worse than the disease.

Mr. C. LIDDELL SIMPSON said he should like to say one or two words about the way the power of the hammer had been reckoned. Anyone who had noticed a steam-hammer would find that it ordinarily made a very short stroke, so that to make a proper comparison of the power exerted by a steam-hammer, this ought to be taken into account. As far as he followed Mr. Samuelson's Paper he did not think that had been done. If the economical working of the power-driven hammers were to be compared with steam-hammers, the steam-hammer exhaust should be either led into a heater or taken into a condenser. Quite recently in his works he had gone into the question of replacing one of the hammers, and he studied the question as to whether it would pay him to put down a power-driven hammer as against a steam-hammer. The only thing that stopped him putting down a power-driven hammer was that the work of his firm was very intermittent and of varied nature, and that power-hammers would not stretch, and the steam-hammer had a greater capacity and was better adapted to the sort of work he had in hand. Another point about the steam-hammer was, that in order to get the best results it was necessary to have small steam-pipes laid to it, and to use if possible superheated steam. When a hammer was treated in that way it was not quite so uneconomical as it at first appeared.

Mr. LESLIE RADCLYFFE said that the "Player" hammer differed from the "Longworth" in taking the power direct from the main crank and not through levers, as would be seen by Fig. 18, Plate 10.

The hammer was driven by means of a crank which worked with a gun-metal block in a steel banjo; the bottom part of this banjo acted as cylinder cover and was bolted direct to the cylinder itself, and driven up and down by the crank, being guided by slides in the main frames. The tup or hammer-head was fastened to the bottom of the piston-rod, and all power transmitted through the crank to this tup by the top or bottom cushion of air in the cylinder. The force of the blow was governed by varying the amount of air-cushion above or below the piston, by means of a series of holes drilled in the cylinder at various heights. The inlet and outlet of air was governed by a valve as shown on Fig. 18 (controlled by means of hand or foot-gear) for opening any one of these holes at will, but only permitting one hole to be opened at one time, thus providing a means of escape for the air. Thus, by having one of the lower holes open, only a small cushion is formed under the piston, and a heavy blow is obtained; if a higher hole is open, one gets a deep cushion and a smaller blow, or the tup may be held off its work altogether. He had found from experience that through the simple construction and few parts 4 B.H.P. was sufficient to drive a 3-cwt. size hammer at 200 revolutions per minute. He used a 24 inches by 4¼ inches pulley with a 4 inches single belt.

With regard to Mr. Simpson's remarks (page 112) about the economy of the power-hammer, it greatly depended on the work to be done, but it was certain that there was no economy in giving light blows with a steam-hammer, whereas with a power-hammer one could give a great number of blows to the same work than with a steam-hammer in the same time and with economy, inasmuch as 75 per cent. of the light blows given by the power-hammer would have to be done by hand and the other 25 per cent. by the steam-hammer. The power-hammer was cleaner, and the amount of work done was directly in proportion to the power used; it could be controlled in the same manner as the steam-hammer, and if only manufacturers would ascertain exactly what the hammer was to be used for, there was no reason why any trouble should follow the purchase of a power-hammer. He did not recommend a power-hammer larger than 10-cwt. size.

The CHAIRMAN asked for how many strokes a minute the hammer was made.

Mr. RADCLYFFE said they were worked up to 500 for the small riveting hammers weighing about 1 lb. The 3-cwt. hammers made 260 revolutions a minute.

Mr. SAMUELSON, in reply, said that in bringing forward the Paper at the request of the Institution he really wished to point out the advantages of pneumatic as against steam-hammers, but only up to certain powers. He did not wish to infer that power-hammers were going to take the place of steam-hammers entirely, as some members who had spoken seemed somewhat inclined to think. Practically speaking he did not think there was a useful power-hammer made at present over 10 cwt., and to hammers of that size and under he would desire the members to consider that he had confined his remarks, and the claims that he had made. Taking firstly Mr. Simpson's question (page 112), he could hardly understand what he said at first, except that he compared the strokes of the hammers and the consumption of steam, and that the steam-hammer was sometimes running light. In the figures given in the Paper he had given the hammer at its heavy stroke, as he thought it was the fairest comparison to make, when both the hammers were doing their utmost work, and he compared the water consumption in the engine driving the power-hammer with the steam consumption in the steam-hammer. With regard to Mr Radclyffe's remarks (page 112), Mr. Radclyffe had introduced a subject which he carefully avoided touching upon, namely, the comparison of various makes of pneumatic-hammers. He thought that better left for discussion outside the Institution. His old friend Mr. Chambers had been somewhat inaccurate. Mr. Chambers received his first power-hammer seven years ago, not five: he had had it for three years before ordering others, and would not let him (Mr. Samuelson) see the work to be done; he tried to ride a steeplechase on a donkey with only partial success. Mr. Chambers also made the remark (page 107) that the hammer, when it was returned, was a wreck. He, Mr. Samuelson, repaired that hammer in 1896, that was after four years' use; he put it into good working order, and sold it to another firm, who were going to run it for ten hours continuously every day, and a week or two ago they asked him for a small repair part to put into the hammer. That was Mr. Chambers' wreck! There was a great secrecy about their work, but he had subsequently found out that Mr. Chambers had been putting the hammers to very severe tests which general users of hammers did not put them to, namely, he had been working on both sides of the hammer tup alternately, as well as in the centre. That answered Mr. Chambers with regard to wear and tear. All the adjustments that Mr. Chambers had asked for had been given to him, except one, which he had only just now found out to be necessary. If Mr. Chambers liked to suggest any more alterations or improvements he should be only too glad to embody them.*

Another remark made at the last meeting was by Mr. Boorman (page 109), who said that single blows could not be given with the hammer. Mr. Chambers very kindly stepped into the breach and said they could, and he himself emphatically confirmed that. With the Longworth hammer the regulation of the blows was exceedingly delicate, and they could be regulated with a very little practice as easily as in striking single blows with the steam-hammer. Mr. Reavell had asked (page 110) whether any experiments had been carried out with compressed-air in steam-hammers. His answer to that was that they had not, and he thought it was rather beyond the question.

Communications.

Mr. DAVID JOY wrote that in 1871 he had made a considerable number of pneumatic power-hammers for forging horse-shoe nails. This hammer was shown in Fig. 17, Plate 10. The tup and air-cushioning piston were actuated through a wood-spring lever by means of a crank driven by a belt, and these hammers struck about

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* Mr. Chambers had now sixteen of these hammers, either at work or on order—June 1900.

(Mr. David Joy.)

500 blows per minute. It is worthy of note that the practical success of this hammer depended on the employment, after many experiments with steel, of wood for the spring lever. Whilst the former reached a cost of 35*s.* per spring, and often failed within a week, the wood, after a little experience in getting the most suitable material (ash) and the right proportions, cost 2*s.* 6*d.* each, and lasted up to three months.

Mr. GEORGE R. PHIPPS wrote that a friend of his was working his steam-hammer in London by compressed air, and considered the result obtained was better than when it was worked by steam, as the cylinders kept cool, and there was no leakage from the glands. His gas-engine worked an air-pump, getting a pressure of 60 lbs. per square inch in his disused steam-boiler; the pipes &c. from boiler to hammer were the same as when using steam, and he stated that economy was obtained by this method.

Mr. SAMUELSON wrote that, whilst his figures given in respect to the power absorbed by the 3-cwt. hammer erred on the side of over-estimating rather than under, he had given in the Paper maximum figures from the diagrams taken in his tests, other cards and figures showing much less power.

In further reply to Mr. Simpson's remarks (page 112), he desired to point out, as he had stated in the discussion (page 114), that his comparison between a steam and power hammer was taken when both were giving their heaviest blow, but that the diagrams and figures on Plate 9 also showed the economy in the necessary driving power, when the power-hammer was running light. It was hardly necessary for him to point out that, whilst Mr. Simpson advocated the use of a condenser, or a superheater, being used in conjunction with steam-hammers, there were few users who would for one minute consider the considerable extra cost of such a plant for such a purpose, and that steam-hammers had necessarily in many instances to be placed at very considerable distances from the boiler. There were no doubt special cases, such as Mr. Simpson's, where users of this class of tool would not find the same economy as others in the use of power-hammers; whilst on the other hand, where continuous work, or difficulty of carrying steam to hammer ensued, the advantages of a power-hammer were obvious.

In reference to the remarks made by Mr. Radclyffe (page 113), whilst not desiring to discuss the comparative values of the various pneumatic hammers in use, he thought that he might be allowed to draw the attention of the members to the great similarity in the design of the Longworth hammer (one of the vital principles of which was its perfect control of the blow by means of air-ports in the bottom cylinder) to that hammer which Mr. Radclyffe referred to. In smaller sizes of the Longworth hammer, a similar form of drive was employed to that used in the "Player," but for the larger sizes he considered the other form as described as being preferable, on account of the lines of force, or action, being kept approximately in a direct line with the centre line of piston-rod, thus obviating practically all tendency to side strains. Whilst Mr. Radclyffe had claimed a fewness of parts for his hammer, he did not point out the more intricate arrangement of valve-gear for controlling the blow, and the additional links, pins, etc., which would be apt in time to become loose, and rattle, and thus to interfere with the delicacy of adjustment in the blow. Further, that whilst the calculation of B.H.P. given by Mr. Radclyffe was taken merely from the diameter of pulley and speed of same, if a similar calculation were made of the 3-cwt. Longworth hammer, it would be found that the same result would be arrived at, and the power given would be nearer 4 B.H.P. than that taken from the diagrams, besides which it would have been interesting possibly to the members to have had a comparison of the work done under the "Player" 3-cwt. hammer and the Longworth, and the net falling weight given of the tool in question.

He also desired to add, in reply to the Chairman's following question (page 114) as to the number of blows per minute for these hammers, that the Longworth hammer was also capable of being varied in design to give as many as 500 blows per minute, down to the number suitable for general forging work, say 130 to 150, and less. This could be verified from the diagrams, from which the

(Mr. Samuelson.)

revolutions of some of the various types of the Longworth hammer were specified, but he considered 260 blows per minute for a 3-cwt. hammer used for general forging purposes was too rapid for a smith to handle his work comfortably under the tool.

PORTABLE PNEUMATIC TOOLS.

By MR. EWART C. AMOS, *Member*, OF LONDON.

The engineering industry at the present time is enjoying a period of activity quite unprecedented in its history, and, as a consequence, is calling for an immense increase in the number of its labour-reducing machines. Prominent amongst these are portable pneumatic tools and appliances; and it is not too much to say that there is every indication of their extended application. They have been used in America for a considerable time, although in this country, with certain exceptions, they have not been so well appreciated until the last few years, and considering their importance and the valuable assistance they are rendering to the shipbuilding and many other industries, it is somewhat singular that comparatively little information has been circulated about them except by trade descriptions. Doubtless some explanation for this is to be found in the fact that their practical application in this country is of comparatively recent date, and further that some of the earlier tools were unsatisfactory. Whatever the cause may be, it appeared to the author that the subject was one which would be of interest to the members of this Institution, and that the valuable discussion likely to arise from such a Paper would be of great benefit to many of our engineers, who may be desirous of obtaining authentic data upon a class of machinery which is likely to prove such a valuable adjunct to their existing types of machines. The author, at the same time, is aware that the subject is by no means a new one to some of the leading and more enterprising firms, who have experimented with pneumatic tools for some years past; and he also recognises that certain kinds of portable pneumatic riveters and other appliances have been in constant use for a considerable time, but he ventures to hope that the various tools described and illustrated in this Paper may be of interest, as showing what has been achieved up to the present date. The various tools which can be driven by compressed air are many, and are rapidly increasing in number; but in order to confine the subject to the limits permitted in a Paper of this description, the author proposes only to refer to portable hammers, riveters and drills, making also a very brief reference to hoists and other appliances driven by compressed air.

Hammers.

Since the mechanism employed for utilising compressed air to secure a percussive action is essentially the same in both hammers and riveters, it will be sufficient to describe the mechanism in one of them only, and for this purpose the hammer will serve.

Hammers may broadly be divided into two types, namely, the valveless hammer and the valve hammer. This is a convenient description, yet perhaps not strictly correct, because, although the valveless hammer has no valve beyond the striking piston, this is itself a valve to effect the proper admission of air to alternate ends of the working cylinder; whilst in the valve hammer, a reciprocating valve, working either at right angles to or parallel with the striking piston, acts in combination with it to regulate the inlet and exhaust of the compressed air. Before coming to a description of these, it may be interesting to set forth the advantages and otherwise of the two systems.

Valveless Hammers have essentially a short stroke, and although economical in air consumption in relation to the number of blows given, they will not compare with valve hammers in giving powerful blows, which are necessary in heavy chipping or riveting. Owing however to their simple construction, they have probably a longer life than the valve hammers, and for such purposes as beading flues, light caulking and chipping, and especially carving in stone, &c., they compare very favourably with their rivals. The speed of the valveless hammers is very high, being 10,000 to 20,000 strokes per minute.

Valve Hammers will probably secure the market for general and heavy chipping, caulking and riveting. Their speed for ordinary work ranges from 1,500 to 2,000 blows per minute, although they can be driven much faster. Their stroke however is considerably longer than that of the valveless hammers and the blow struck correspondingly greater.

There is more air lost in the ports, but other advantages, including better control for using the air expansively, overcome this small defect. It is well known that the nature of a blow (whether light or heavy) on various materials, produces an effect apart from the actual work done as measured in foot-pounds. For example, 10,000 small blows representing a certain number of foot-pounds might fail to produce a desired result, which a smaller number of heavy blows, representing less energy in foot-pounds, might effect.

Having now considered the claims and advantages of the different types of hammers, all of which it may be stated can be worked economically at from 60 lbs. to 80 lbs. per square inch, reference must be made to the illustrations in order to explain their construction and action under compressed air.

"*Ross*" *Hammer.*—Fig. 1, Plate 12, shows in section a "Ross" hammer, in which the striking piston becomes the valve to control the admission and exhaust of the working fluid. A represents the outer casing, made from solid drawn steel tube, bored and fitted with a phosphor bronze liner B, which forms the cylinder in which the piston works; E, the striking piston made from a steel forging, ground to fit the cylinder; D, the exhaust ports, open to the atmosphere through the valve G; C and P, the admission ports, admitting live air to alternate ends of the piston; K, another port always open to the air-supply; G, the exhaust valve; H, the trigger actuating the same; F, the phosphor bronze handle, to which live air is admitted at the point F^1; L, a piston cushion, has always full and constant pressure behind it from the air-supply through the port L^1; and M shows the working tool.

It must be noted that this hammer is caused to work by the opening of the exhaust, and not by regulation of the admission. The direction taken by the fluid under pressure, when connected to the handle at F^1, will be readily seen by noting the arrows. The piston is slightly reduced in diameter in the middle, and the inside edges of the two collars thus produced form the cut-off edges for pressure, whilst their outsides govern the exhaust ports. It will be readily seen that, when the piston is in the middle of its stroke, there is a dead point, the live air only finding admission to the chamber formed by the reduced portion of the piston, since the ports C and P are both cut off from admission of live air, but this does not interfere with its proper working as the lap is very small. Moreover, when starting, the piston will fall either to one end of the cylinder or the other by gravity, and when at work the momentum carries it over the dead point. The diagram shows the front exhaust-valve open, and the piston just commencing to make its forward stroke. Air flows through K thence through C, passing between the annular space formed between the liner and the outer casing, and through C^1 to back of piston, thus driving it forward. At the same time, exhaust takes place from the front of the piston through D. The same action takes place on the rearward stroke, when the forward ports P and P^1 are then in communication with K. In order, as far as possible, to eliminate vibration, a condition which is present in all hammers, the cushion piston L has been introduced at the rear of piston.

"*Q and C*" *Hammer.*—Fig. 2, Plate 12, shows in section a "*Q* and *C*" single hammer. A represents a bronze handle, into which is fitted the steel liner B, which forms the working cylinder ; C, the striking piston, which acts as its own valve ; D, the outer cap, connecting the liner to the handle ; E, the throttle valve ; F, the trigger actuating same ; and G, the point to which the air-supply is attached. The action of the hammer on the trigger being depressed is as follows :— The air having passed the valve E flows along the passage *d*, and through a large air-port into the cylinder or pressure chamber ; this has the effect of maintaining a constant pressure under the shoulder of the piston, and tends to drive it backwards. When however the ports *b* in the piston C, which are also large openings, come into communication with the cylinder, the pressure fills the hollow portion of the piston and the cylinder in its rear, driving the piston forward to strike its blow. At this instant, however, the piston ports come into communication with the exhaust port *c*, when the pressure under the piston shoulder again returns the piston and the blows are repeated in rapid succession—it is stated as many as 10,000 to 20,000 per minute. It will be noticed that in this arrangement of ports the air is used expansively. The same type of hammer is made in a modified form, being provided with a second piston placed in the rear of the other, the actuating fluid working between the two pistons for the forward stroke. It is claimed for this that vibration is reduced to a minimum.

Coming now to the valve hammers, to describe them briefly, and the same time accurately, is not an easy matter, because although they are simple in action and not excessively complicated with regard to the number of working parts, yet their movements and arrangements of ports are such as to make their description somewhat difficult. The author has however endeavoured to be as brief as possible while at the same time referring to their essential features.

"*Little Giant*" *Hammer*.—This is illustrated in Figs. 3 to 8, Plates 12 to 14, to which the following key applies:—A, working cylinder; B, piston hammer; D, working tool; E, controlling valve; E^1, steel seating for same; F, handle; G G^1, throttle valve bushing; H, throttle valve; I, trigger actuating same; *a*, bore of cylinder; a^1, passage leading from space *e* to the cylinder, and always full of fluid pressure when throttle valve is open; a^2, passage leading from cylinder to top of valve chamber; a^3, passage from front end of cylinder to annular space e^3 in valve chamber; a^4, exhaust passage at rear end of cylinder leading to exhaust through interior of valve; a^5, bye-pass from a^2 to cylinder; a^6, bye-pass from cylinder to a^7; a^7, exhaust passage in forward end of cylinder to atmosphere; *b*, reduced portion of striking piston; b^1, annular chamber formed by such portion; *e*, opening into the controlling valve bushing; e^1, opening into cylinder from valve bushing; e^2, cap on top of valve bushing; e^3, annular portion in valve bushing; e^4, openings in valve E leading to exhaust port e^6; e^5, central chamber of valve;

e^6, exhaust to air in handle; e^8, enlarged diameter of valve for cushioning; e^9, recess behind e^8; e^{10}, small boss on top of valve. Fig. 3 represents a longitudinal sectional elevation of a hammer with the striking piston at the rear end. Fig. 4 is a similar view, but of the opposite half, and showing the striking piston at the forward end of stroke. Figs. 5 and 6 show the handle and valve portion in section with the valve at the top and bottom positions respectively. Figs. 7 and 8 show horizontal sections taken on lines X and Y of Figs. 5 and 6 respectively.

The action of the tool is as follows:—Fluid under pressure having been admitted by operating the valve H, passes through the opening e, and under the head of the valve E, thus forcing it into the position shown in Fig. 5. The air is then able to pass into the cylinder, through the opening e^1, and this forces the piston forward into the position shown in Fig. 4. It will be noted that the piston is reduced in diameter at b, which together with the cylinder forms a chamber b^1, so that as the piston nears its forward limit of stroke, fluid pressure enters the chamber b^1 from the passage a^1, which is in direct communication with space e. At the same time the passage a^2 is brought into communication with b^1, and thus the air passes along to the top of the valve E, and forces it into the bottom position as shown in Figs. 3 and 6. When the valve is in this position, a clear way for the compressed air is open to the front end of piston through e, e^3, and a^3, thus effecting the return of the piston. Thus far the live air admission has been dealt with to drive both piston and valve in both directions. Coming now to the exhaust and taking the piston in its rearward motion first, the air escapes along the passage a^4 and through the openings e^4 in valve and out through e^6. In its forward motion the piston exhausts first through a^7, which leads direct to outer atmosphere, see Fig. 4. When a^7 is passed, the air escapes through a^3, which is open to atmosphere through e^3, e^4, and e^6, when the valve E is up. The exhaust of the valve is effected thus:—During the backward movement of the piston and as its annular portion is passing the orifice of a^2, it permits the fluid pressure on top of valve E to escape through a^2 and a^5 into b^1, a^6 and a^7, to atmosphere, with the result that superior pressure under valve head from e again lifts the valve. The valve is forced into its bottom position due to its area on the top being larger than the ring underneath its head. It is obvious that both the striking piston in its backward stroke and the valve in both directions should receive some form of cushioning, so as to reduce shock, and prevent injury to valve and cylinder. In the piston this is effected by its closing the port a^4 before the end of its stroke. In the valve the desired cushioning is secured in its upward stroke by means of the boss e^{10}, which causes the air to escape rather slowly into a^2. In its downward stroke the cushioning is effected thus:—The portion e^8 of the valve E is of a diameter nearly equal to the small bore of the valve bushing, and there is also provided a small groove e^9, Fig. 5. When the valve is moving down, the portion e^8 first enters the small bore of the valve chamber, and this tends to retard the passage of the air through the bore, and permits the excess of air to act as a cushion. Up to a certain limit the same hammer may be used to give light or heavy blows, and this may be effected by regulating the amount of opening given to the throttle valve. It is not desirable however to simply rely upon the trigger to do this, but preferably to provide a regulator, so that however hard the trigger may be pushed it only opens the valve the desired amount. In the "Little Giant" hammer this result is obtained by making the throttle-valve bushing in two portions, G and G^1. The part G is fixed to the handle whilst G^1 is capable of being screwed in or out. The effect of this adjustment, when taken in combination with the valve H and the trigger I, is such that when G^1 is unscrewed, the port g^1 may be moved into such a position that the valve H can be pushed by the trigger I to the limit of its stroke without uncovering the port g^1 at all, and by adjustment of the part G^1 any desired opening may be given for the admission of air. In order to put the valve H in equilibrium a small opening admits the compressed air to either side of it, which, together with the spring shown, effects the desired result. It will be obvious that fewness of parts, and especially of joints, are desirable in the construction of a tool using compressed air at a high pressure, since the possibility of leakage is thereby considerably reduced. The question of joints is of necessity more difficult to deal with in a valve hammer than with a valveless hammer, but in the "Little Giant" type this danger has been reduced to a minimum, by dispensing with a valve block and inserting the valve bushing direct into the handle, whilst the cylinder portion A is securely fixed to the handle F by means of a sleeve K. Another feature of this hammer is the economical use of the compressed air, due to the cushioning of the moving parts taking place on the exhaust air rather than from the admission of live air, and taking this in connection with the solid construction of the valve, the same being well cushioned in both directions of its travel, the "Little Giant" type is likely to prove both an economical and a good wearing hammer.

"*Boyer*" *Hammer.*—Figs. 9 to 14, Plate 14, show several sectional views of a "Boyer" hammer, in which the following letters of reference indicate the various parts referred to:—A, the working cylinder; D, the handle; G, the air passage from throttle valve to cylinder; G^1, throttle valve; H, trigger actuating same; I, the valve block; I^1, cap at end of same; K, the working tool; M, the piston, consisting of a solid piece of turned steel fitting the bore of the cylinder and provided with a recess M^1; O, the valve; P, passage from cylinder to small space *e*; Q, passage from cylinder to small space *n*; R, passage from front end of cylinder to small space *m*; S, port leading from space *e* to front of cylinder through passage R; T, passage from cylinder through U to space *e*; T^1, from air-supply to cylinder; X, from air-supply to *e*.

X is only necessary to supply fluid to front end of piston *via* S and R and to hold the valve in rear position. Other letters on the drawings are referred to in the following description of the working of the hammer:—Figs. 9 and 11 represent the piston in its forward, and the valve in its rearward position. The motive fluid having been admitted passes along the passage G and then through W into space e^1 and acts on small area *d* of the valve O, and tends to force the valve forward, but fluid pressure in space *e* admitted by the passage X acting upon the large area *c* of the valve O will hold the valve in the rearward position against the pressure acting on the small area *d*. The fluid will pass from space *e* through passages S and R to the front end of the piston driving the latter backward, the rear end of the cylinder being open to exhaust through the slots *l* in valve O and groove *h*, the latter being constantly open to the atmosphere through passages *i*, *j*, *k*. As the piston moves backwards, it uncovers ports P and Q, and the pressure in front end of cylinder will exhaust through passage Q *via* the groove *n* and passages *o*, *i*, *j*, *k*, to the atmosphere; the front end of the passage P will be uncovered by the front end of the piston at the same time as the front end of the passage Q and the fluid in space *e* will escape through passages P Q, groove *n*, and passages *o*, *i*, *j*, *k*, to the outer air. Passage P being larger than passage X by which the fluid is supplied to the space *e*, the pressure on the large area *c* of the valve O will be greatly diminished, so that the pressure acting on the small area *d* of the valve O will force the valve forward to the position of Figs. 10 and 12, whereupon the ring *b* of the valve O will close the passage X and cut off the supply of fluid to space *e*, thereby permitting pressure at *d* to hold the valve in the forward position. The annular space *p* will now be opened from which fluid pressure *via* W and e^1 will pass to the interior of the valve, and acting on the rear end of the piston will first bring it to rest forming a cushion and later drive the piston forward. As the piston moves forward and finally strikes a blow on the chisel the air in front can escape through passage Q until the latter is closed by the front end of the piston and thereafter can escape through passage R, grooves *m*, *a* and *n*, and passages *o*, *i*, *j*, and *k*, to the atmosphere. When the piston is moved so that T and T^1 are in communication *via* groove M^1, fluid under pressure will pass *via* T^1, M^1, T and U to space *e*, and acting on the large area *c* of the valve O will overcome the constant pressure on its small area *d* and force the valve backward, and thus open X, admitting more fluid to space *e* to hold the valve in that position; also fluid will pass from *e* to R *via* S and to the front end of the piston to assist in driving the piston back. The recoil accomplishes most of the return of the piston. During the backward movement of the piston, the end of the cylinder is open to exhaust through slots *l* in the valve O and groove *h* and passages *i*, *j*, *k*, until the passages P and Q are uncovered by the front end of the piston, at which time the valve opens, and, admitting fluid, arrests the piston and drives it forward. Although communication between T and T^1 is cut off almost directly the piston commences its backward movement, the valve O will not change its position (from rear to front) because sufficient fluid pressure is passing into space *e* through passage X to hold the valve notwithstanding the escape of the fluid *via* S, since the latter is of less capacity than X. It will be readily understood that the action of the compressed air along the passage G, acting first on one area and then on another area of the valve O, drives it in alternate directions, and that the valve in turn admits air to either end of the cylinder; at the same time the piston opens and closes certain ports in the cylinder as in the case of the valveless hammer, and the combination of the dual motions of the valve and the piston produces the desired result of causing the piston to rapidly reciprocate and deliver a number of blows upon the tool K. In this hammer it will be noted that the striking piston passes through the valve, which has the effect of increasing the stroke of the piston as compared with the original design of the hammer (in which the valve was arranged in a separate chamber immediately in the rear of the piston chamber) and without increasing the overall length. In order to effect a cushion on the piston on the rearward stroke live air is admitted before such stroke is completed. With regard to the valves, owing to their extreme lightness and shortness of stroke, it is stated that cushioning of the valve is unnecessary.

Having now described four representative types of hammers which may fairly be said to cover the types at present in use, it may be interesting to refer to Table I (page 129), showing sizes and air-consumption, but in regard to these the author wishes to point out:—(1) That they are as given by the different makers. (2) That the claims as to air-consumption can only be sustained when the tools are in the hands of competent workmen, as otherwise the air consumed may greatly exceed the quantities given. (3) That the air-consumption is not alone indicative of the efficiency of the tool.

The author however, whilst putting against each maker the amount claimed by him as being the amount of air consumed, is inclined to think that these amounts may be a little exceeded, and in any case provision must be made for leakages, &c.; it is therefore

TABLE I.—*Table showing sizes, weights, and approximate air-consumption of Hammers.*

Type.	Description number.	Length of Stroke.	Diam. of Piston.	Weight of Piston.	Estimated Speed.	Air-Consumption in Free Air.	Weight of Hammer.
		ins.	ins.	ozs.	Blows per min.	cub. ft. per min.	lbs.
"Ross." Fig. 1. Plate 12.		$\frac{7}{8}$	$1\frac{3}{4}$	$2\frac{1}{2}$	11,000	30	$11\frac{1}{2}$
		$\frac{13}{16}$	$1\frac{5}{8}$	2	,,	25	$10\frac{3}{4}$
		$\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	,,	18	$10\frac{1}{2}$
		$\frac{11}{16}$	$1\frac{3}{8}$	$1\frac{1}{2}$	,,	15	$6\frac{1}{2}$
		$\frac{5}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	,,	13	6
"Q and C." Fig. 2. Plate 12.	Single Hammer C	1	$1\frac{1}{2}$		10,000 to 15,000	12	$5\frac{3}{4}$
	Single Hammer D	$\frac{1}{2}$	$1\frac{1}{2}$			12	$5\frac{1}{4}$
	Single Hammer F	$\frac{1}{2}$	$1\frac{1}{4}$			10	$3\frac{1}{2}$
	Double Hammer A	1	$1\frac{3}{4}$			18	$10\frac{3}{4}$
	Double Hammer C	1	$1\frac{1}{2}$			15	$9\frac{1}{4}$
"LITTLE GIANT." Figs. 3 to 8. Plates 12–14	0	5	$1\frac{1}{8}$	20	1,200	20	16
	1	4	$1\frac{1}{8}$	16	1,500	15	12
	2	3	$1\frac{1}{8}$	14	2,000	15	$9\frac{1}{2}$
	3	$2\frac{1}{4}$	$1\frac{1}{8}$	14	2,000	15	$8\frac{1}{2}$
"BOYER." Figs. 9 to 14. Plate 14.	000	5	$1\frac{5}{16}$	34	1,000	20	26
	0	5	$1\frac{1}{16}$	$23\frac{1}{2}$	1,800	20	13
	1	4	$1\frac{1}{16}$	17	2,200	15	$9\frac{3}{4}$
	2	3	$1\frac{1}{16}$	13	2,600	15	$8\frac{1}{4}$
	3	$1\frac{3}{4}$	$1\frac{1}{16}$	13	3,000	12	$8\frac{1}{4}$
	B	2	$1\frac{3}{16}$	12	3,500 to 5,500	10	8
	BB	$1\frac{3}{4}$	$1\frac{1}{16}$	8		10	$6\frac{1}{2}$
	F	1	$\frac{3}{4}$	4		10	4
	U	$\frac{3}{4}$	$\frac{5}{8}$	3		10	3

not advisable to cut down the air-supply to these amounts, and in actual practice some margin must be provided over and above what the experimental trials would seem to indicate the tools require.

Some reference must now be made to vibration, and its effect upon the operator. Some hammers vibrate more than others, but even in the best the shock is noticeable. Its effect however is greatly reduced as soon as the operator learns how to use the hammer to its best advantage, and it is probable that no injury will be done to the operator as soon as he has adapted himself to its proper handling. The purposes to which these hammers may be applied are many, and include chipping, caulking, beading, fettling, scaling, riveting, stone-dressing and carving, driving plug-holes in stone, planishing brass and copper, driving nails and spikes, &c. To whatever purpose however the hammer may be put, it is necessary to remember that proper efficiency can only be obtained by selecting hammers of suitable weight and stroke for each class of work. No tool can be adapted to all classes of work. It is not uncommon to find operators attaching blame to a tool on account of its failing to successfully do its work when the real cause of failure is due to the application of the wrong tool. For results of work done by hammers in caulking, chipping, &c., reference must be made to Table IV, page 147.

Riveters.

Compressed air has long since been recognised to possess great advantages for the purposes of riveting. Portable pneumatic riveters may be divided into two types, namely, those that effect their purpose by squeezing, and those that have a percussive action. The former type are well known, and it is therefore proposed to consider only the latter. These again may be sub-divided into (a) hand-riveters, used in conjunction with a pneumatic holder-up, and (b) yoke riveters.

Hand-Riveters.—The hand-riveter is simply a heavy pneumatic hammer fitted with suitable snaps, and therefore it becomes unnecessary to describe its mechanical action. It should be mentioned however that when used for riveting air-pressure up to 100 to 125 lbs. is advantageous. In the hands of a skilful operator, this tool will be found exceedingly useful, as it can be extensively used in shipbuilding and constructional ironwork to drive rivets in places inaccessible to a yoke or bear riveter. At the same time, in the hands of an incompetent or lazy workman, it lends itself to doing anything but satisfactory work, as care is required to avoid making the head of the rivet on one side. It is of course necessary to have a holder-up, and this usually takes the form of a simple piece of mechanism consisting of a piston working in a cylinder into which compressed air is admitted, the end of the piston being kept up to the rivet-head by the fluid pressure.

Under this heading may also be described shell-riveters, which are hand-riveters mounted in a gimbal or suitable pivoted frame, which permits of shell-rivets being driven up to a considerable size, and in places where a yoke riveter is unworkable. These are exceedingly valuable for shipwork.

"*Boyer*" *Long-Stroke Hammer.*—All the hammers that have already been described may be used for hand-riveting, but it may be interesting to refer to the 9-inch stroke "Boyer" hammer shown on Fig. 45, Plate 25, in which A is the barrel, B the bushing forming the working cylinder in which the striking piston C works. D is the handle, E the trigger for actuating the admission valve as in an ordinary hammer. F is a nose piece which receives the stem or shank of a riveting-tool or snap G. G^1 is a spring clip which detachably connects F and G. H is an air chamber. I is a sleeve which is actually a second throttle-valve independent of that in the handle. J and J^1 are two valves at the rear and forward end of the cylinder respectively, and these valves control the air-supply to the piston. They are connected, or have interposed between them, two small rods or wires K and K^1 extending longitudinally through the cylinder wall from one end to the other, so that when the valve J^1 moves backward its movement will be communicated to the valve J, or when the valve J moves forward it communicates a like movement to J^1. The rods are not attached at either end of the valves, although the action would be the same if they were. L is one of two rods which abut at their rear ends against the throttle-valve I and at their forward ends against a sleeve M. It is not proposed to give a full and detailed description of the working parts, since this has already been done when describing the "Boyer" hammer.

It will therefore suffice to say that in order that the tool may start working (the handle throttle-valve having previously been opened) the rivet snap G must be pressed against its work. This opens the throttle-valve I by means of the rods L to admit air to the cylinder through the automatic controlling valves J and J^1. The reciprocation then takes place as in an ordinary hammer. By this means the compressed air is not only automatically admitted to the tool by the act of pressing the latter up to its work, but the tool is inoperative unless it is pressed against the work. This provision for preventing operation of the tool except when pressed to its work is of importance, since otherwise the tool might be run without the presence of anything to resist the powerful blows of the long-stroke piston, which might be liable to knock off the entire front end of the tool. The object of the valve at either end is to secure a longer stroke than would otherwise be possible, and is the feature of the hammer.

Yoke Riveter.—Figs. 15 and 16, Plate 15, illustrate an ordinary yoke riveter suitable for shipwork and constructional ironwork generally, tanks, gasholders, wagon under-frames, and a variety of other purposes. One arm of the yoke is fitted with what is practically a percussion hammer, whilst on the other is a solid holder-up. Suitable adjustment of the hammer portion permits of the snaps being the correct distance apart. In a riveter of this type, great as is its value for certain classes of work, no provision is made for closing the plates, except that which may result from the snapping of the rivet; and to obviate this difficulty and to supply the want of a percussive-action plate-closing riveter, the "Little Giant" yoke riveter, which is shown in Figs. 18, 19 and 20, Plate 16, has recently been made. This riveter consists of an ordinary yoke *a*, having at one end a fixed holder-up and at the other a small frame or yoke carrying a pneumatic hammer, and provided with a special clamping device for clamping the work together during the process of riveting. This clamping device also takes the place of the ordinary pneumatic holder-up. Fig. 20 shows the device in section and the rivet in position with its head against the fixed holder-up and through the work to be riveted together, whilst the hammer and clamping device are in their normal position before live air is admitted.

Fig. 18 is a similar view, but with the clamping device shown against the work in readiness for the hammer to commence the operation of riveting the head. Its action will be readily understood by a short description, reference being had to the letters shown on the drawing, in which a is the main yoke; a^1 the small yoke or frame carrying the percussion hammer and clamping device g; b a projection of a^1; c an air chamber formed by the extension of the back of the hammer and the projection b; d the said extension of the hammer casing, and which also forms a guide to carry the hammer; e the hammer cylinder; f an extension of the coupling sleeve of hammer, and which slides in the other end of the small yoke a^1, and also acts as a guide for the clamping device; h a spring for returning g to normal position when air-pressure is cut off; h^1 the hammer piston; i the tool shaped to form the head of the rivet; j, j^1 and j^2 ports for air-supply; k distributing valve; l and m exhaust and supply as in an ordinary hammer; n the rivet. The action is as follows:—The work to be riveted being in position, as shown in Fig. 20, air is admitted through k and into the passage j. This forces the whole apparatus forward until the tool i is in contact with the rivet and forces it against the fixed holder-up. At the same time live air is admitted through j^1, forcing the clamping device g forward, as shown in Fig. 18, which closes the plates, and permanently holds them in position, whilst the rivet-head is being formed. As the rivet gets shorter the constant pressure in the space c keeps the hammer to its work. The action of the hammer has already been described, the air-supply to the striking piston being regulated by the valve o. Fig. 19 is a section on the line AA, and shows the air passage from the valve k to the regulating valve o and also to the cylinders.

It will be obvious from this description and the drawings shown that although it is not possible to get a very great pressure on the clamping device without increasing the area of the pressing cylinders to an abnormal amount, yet this arrangement possesses very considerable advantages over the ordinary percussion yoke riveter, as it ensures that the riveting hammer shall be automatically kept up to its work, and that the work shall be firmly held together whilst the rivet is being driven, both of which are very important points.

Another and very valuable form of riveter is that shown in Fig. 17, Plate 15. This shows the "Little Giant" light yoke riveter, and represents the very latest development, which should prove an exceedingly useful addition to the pneumatic appliances at present in use. Its simplicity and value will be at once appreciated by reference to the diagram, in which A represents an ordinary standard type "Little Giant" hammer as used for chipping or riveting, clamped to a light yoke B carrying at its other end a pneumatic holder-up C. There is also clamped to the yoke B a small casing D, containing an air-chamber E, valve F, trigger G, and suitable pipe connections for providing compressed-air communication with the hammer A and holder-up C. The action is as follows: The main air-supply enters the chamber E at H, being admitted past the valve F by pressing the trigger G, and thence passes to the holder-up and hammer-handle. The holder-up at once brings the rivet into its place, and the operator then puts the hammer in action in the ordinary way by depressing its trigger I. The object of this riveter is to replace a separate holder-up in light riveting work where a yoke is permissible. To deal with such work it has hitherto been necessary either to use a hand-riveter and separate holder-up, thus requiring two operators, or else a yoke riveter, which is generally too cumbersome for one operator. Moreover it ensures that the holder-up first brings the rivet home before the percussion action begins, and also makes it possible to use an ordinary hammer. This would prove a very useful feature should anything go wrong with the percussion mechanism, when the hammer could be easily unclamped and immediately replaced. Such a riveter would close $\frac{5}{16}$-inch cold rivets or $\frac{3}{8}$-inch hot rivets with a gap up to about 12 inches, and could easily be handled by one man. With regard to the respective advantages of percussion riveters and squeezing riveters, especially of the hydraulic type, there is considerable difference of opinion. In this country we have so long been used to hydraulic-squeezing riveters that the percussion-riveter at first met with but scant recognition until its advantages were proved, and the author ventures to think that a solution of the difficulty will be found when the true value of each type for its respective work has been fully recognised. To those who have tried both systems, the pneumatic percussion-riveter has shown itself to possess certain advantages in the form of lightness, portability, convenience in manipulation, and other points over its rival. On the other hand the advocates of the percussion system do not at present claim advantages where the riveted work has to stand high pressure as in boiler work, although the "Little Giant" plate-closing yoke riveter is certainly a step in the direction of using it for this purpose.

Table II (page 136) gives a comparison between pneumatic-machine and hand-riveting in the Chicago shipyards.

Portable Drills.

The many advantages to be derived from the application of compressed air for the purpose of driving portable drills are probably more apparent than in the case of either hammers or riveters. In the author's opinion, the portable pneumatic drill, with its many applications, will soon be recognised (if it is not already) as one of the most important additions that have been made in recent times to our stock of labour-saving machines. A great deal of work, which for economic reasons had before to be drilled in the shop previous to erection, can now be drilled *in sitû*, and the result, besides being more satisfactory in itself, has considerably reduced the cost. Besides drilling, portable pneumatic drills can be used for reaming, tapping, tube expanding, cleaning castings, boring wood, screwing nuts on to bolts, boring cylinders and Corliss valve seats, grinding steam-pipe joints, turning up crank and car-wheel pins in position, and a variety of other purposes which will readily suggest themselves. The method by which compressed air is utilized for

TABLE II.

Comparison of Cost between Machine and Hand-Riveting at Chicago Shipyards.

(Taken during three weeks ending 12 October 1899.)

Distribution.	Number of Rivets.	Diam. of Rivets.	Machine Rate each.	Hand Rate each.
		Inch.		
Keel	6,217	1	2½ cents.	4½ cents.
Shell	21,628	⅞	1¾ ,,	3½ ,,
Shell Margin (bilge single line)	1,122	⅞	3 ,,	4½ ,,
Longitudinals open . .	24,632	¾	1¼ ,,	2¾ ,,
C. V. K. Brackets . .	3,197	¾	1 ,,	3½ ,,
,, ,, . .	—	—	1¼ ,,	3½ ,,
,, ,, . .	—	—	1½ ,,	3½ ,,
Longitudinals under tank .	664	¾	1¾ ,,	2¾ ,,
Longitudinal bars . .	2,989	¾	1¼ ,,	2¾ ,,
Tank-top Stiffeners . .	1,129	¾	2½ ,,	3½ ,,
Tank-top Margin . .	4,033	¾	1½ ,,	2¾ ,,
Tank-top Lugs . . .	1,520	¾	1¾ ,,	3½ ,,
Tank-top Rider . . .	3,209	¾	1¼ ,,	2¾ ,,
Tank-top	4,467	¾	1¼ ,,	2¾ ,,
C. V. K. Cross Vertical Kelson	12,723	¾	1 ,,	3 ,,
Hold Stringer . . .	1,184	¾	1½ ,,	3 ,,
Floors	123	¾	1¼ ,,	3 ,,
Floors (odd) . . .	5	¾	2 ,,	6 ,,
C. V. K. (odd) . . .	38	¾	2 ,,	6 ,,
Bulkheads	1,318	¾	1¼ ,,	5 ,,
,, ...	3,051	¾	1¾ ,,	3¼ ,,
,, ...	231	⅝	1½ ,,	2½ ,,
Total . .	93,480			

Total cost by machine, 1,403·31 dols. Average 1·50 cents each.

,, ,, by hand would have been 2,986·87 dols. Average 3·19 cents each.

Saving 1,583·56 dols. Average 1·69 cents each.

Average cost of machine riveting was 47 per cent. of hand cost.

driving the drills is generally by means of single or double-acting cylinder motors, the cylinders of which are sometimes fixed and sometimes oscillating and these again actuate suitable mechanism for driving the bit, and are encased in the body of the drill. The piston air-drill, as it may conveniently be termed, has become a very important factor in boiler work, shipbuilding and constructional work generally. As a reamer or tube expander the saving over hand-labour is very great, and at the same time the work is turned out much faster—a great point in shipbuilding. Pneumatic drills are made in a large number of sizes, from light drills suitable for small holes up to powerful ones developing two to three horse-power. The latter are capable of driving bars for boring work in position, or re-turning crank-pins, &c., and their range of usefulness is very large. They can be worked economically with 60 to 80 lbs. of air pressure.

Fig. 21, Plate 18, shows an outside view of a "Little Giant" portable air-drill. Fig. 22, Plate 18, is a longitudinal sectional elevation taken on lines 1–1 of Figs. 23 and 24. Fig. 23 is a cross sectional view taken on line 2–2 of Fig. 22. Fig. 24 is a similar view taken on line 3–3 of Fig. 22. In this type of drill the motor consists of four single-acting cylinders arranged in pairs, and having each pair of pistons connected to opposite ends of a double crank-shaft. The pistons of each pair travel in opposite directions at all parts of the stroke to effect smooth running. The cylinders are controlled by balanced piston-valves set to cut off at 5-8ths of the stroke and should therefore prove economical. Referring to Figs. 21 to 24, A is the main casing, which contains the mechanism; B and B^1 are one pair of cylinders, and C and C^1 the other, and arranged at right angles to each other and connected to a common crank-shaft D. By this arrangement a dead centre is avoided. The air admission and exhaust is controlled by two piston valves E and E^1, shown most clearly in Fig. 23. These are worked by small eccentrics off the crank-shaft, and serve to control the four cylinders; *f* is the main pressure chamber, having communication with the supply pipe H. Fig. 23 shows one of the piston-valves in section, from which it will be seen that it is reduced in diameter in the centre, and is hollow.

The arrows show the direction taken by the air. Cylinders B and B^1 receive air-communications through f^2 and f^3, and cylinders C and C^1 through c^3 and c^4, the exhaust taking place through the interior of the two valves. Fig. 23 shows the action to be as follows; f is full of live air which is blowing through c^4 and f^3, to supply cylinders C^1 and B^1, whilst cylinders B and B^1 are exhausting through f^2 and c^3 into the centre of the valves and thus to the atmosphere. Referring to Fig. 22, k and k^1 are gear wheels by which the rotary motion of the crank-shaft is conveyed to the part K, which is fitted with a suitable drill holder or chuck. L is a threaded sleeve, which, in conjunction with L^1 and other parts, provide for the feeding down of the drill. This tool can also be fitted with a simple reversing arrangement, which enables it to do all classes of work for which a drill is suitable; this is shown in Fig. 25, a handle taking the place of the star centre shown on Fig. 21. By revolving this handle a valve placed in the main pressure chamber reverses the direction taken by the air when entering the valve bushing, suitable ports being provided. The drill is thus capable of dealing with work, where reversing is necessary, as in tapping, tube expanding, wood boring, &c. Pneumatic drills of this description are now used at the carriage department of the London and North Western Railway Works at Wolverton driving saw-bits for the purpose of cutting out the lamp holes and openings for the heating apparatus in railway carriages. This is the first application of its kind.

Fig. 26, Plate 19, shows the interior of a "Whitelaw" drill with half the casing removed, whilst Fig. 27 shows the passage of the air leading to the cylinder and the method of reversal. This type of drill is actuated by two double-acting oscillating cylinders A and B, driving a crank-shaft C, to which is attached a pinion D driving the gear wheel E, attached to the drill spindle. Its action is therefore at once seen, and reference to the cross section, Fig. 27, will show that by rotating the milled handle F which gears into a short rack G at the end of the lever H, the hollow portion I changes its position, with the result that reversal takes place in the usual way adopted in oscillating cylinders. The exhaust is made into the casing and escapes through suitable apertures. The reversal is instantaneous, and the machine is well adapted for all kinds of drilling, tapping, tube expanding, wood-boring, &c., the reversing arrangement especially lending itself for such purposes. The machine is supplied with ample lubrication, and is fitted with ball bearings throughout.

Fig. 28, Plate 20, illustrates a transverse vertical section of a "Boyer" piston drill, and Fig. 30 is a horizontal section taken through the centre of the cylinders. The machine consists of three main parts; (1) The upper housing into which the throttle valve and steadying handle are screwed, and which forms a live-air chamber carrying the motor; (2) The diaphragm which forms the lid or cover of the upper housing or live-air chamber, and through which the hollow exhaust spindle projects; (3) The lower housing secured to the upper housing by means of screws, and containing the gear wheel rack, bearings for drill spindle, &c. The motor is in the form of a three-cylinder single-acting oscillating engine, the cylinders being

TABLE III.—*Pneumatic Drills.*

Type.	Descriptive number.	Weight.	Revolutions per minute, machines unloaded.	B.H.P.	Air-Consumption in Free Air.	Maximum Duty.
		lbs.			cub. ft. per min.	
"Little Giant." Figs. 21 to 24, Plate 18.	0	45	125	2¼	45	3" holes in metal.
	1	35	190	1½	35	2" ,, ,, ,,
	2	19	250	1	25	1¼" ,, ,, ,,
	3	8	750	..	15	½" ,, ,, ,,
"Whitelaw." Figs. 26 & 27, Plate 19.	4	..	1,000	¼	15	¼" holes in metal.
	6	14	720	¾	20	3" holes in soft wood.
	7	20	250	1	25	For tube expanding.
	8	39	120	1½	30	3" holes in metal.
"Boyer." Figs. 28 to 30, Plate 20.	2	46	180	1¼	30	3" ,, ,, ,,
	3	41	240	1	25	1" ,, ,, ,,
	6	17	500	¾	20	¾" ,, ,, ,, 3" holes in soft wood.

carried in a rotary frame. This frame consists of an upper and lower plate, and is triangular in shape as shown in Fig. 29, and is free to revolve round its centre on two bearings, the lower one being a hollow shaft, and connected by gearing to an internally toothed wheel in the lower half of the casing. The admission of air to the cylinders is regulated by the valves formed in the pivots upon which the cylinders vibrate. The cylinders are single acting, and the inner ends are open, and therefore air under pressure, of which the upper casing is always full, has free access to the pistons on that side. It would seem therefore, that air being admitted through the pivot valves would only produce equilibrium, but since one of the cylinders is always open to the exhaust through the hollow bearing of the triangular frame this equilibrium becomes disturbed, and the compressed air has full effect upon each piston as the valve comes in line with the exhaust. The cylinders are constructed of steel tubes, and are fitted with trunk pistons having their connecting-rod ends attached to a fixed crank-pin common to them all; the pistons having been set in motion by the introduction of compressed air into the upper casing, and into the cylinder as already described, has the effect of causing the three cylinders, together with their triangular framing, to rotate round the fixed crank-pin, and thus transmit rotary motion to the spindle by means of the gearing before referred to. This class of machine is fitted with a regulator by means of which the power and speed of the drill can be varied as desired.

Figs. 31 to 35, Plate 21, illustrate the "Little Giant" high-speed rotary drill, which consists of a casing C containing three rotating cylinders F, each of which is governed by a piston slide valve E. These valves rotate with and work in cylinders or valve chambers forming part of the main engine cylinders F. In other machines for effecting the same and similar purposes the casing is used as a live air chamber; in the "Little Giant" type it is used as an exhaust receiver. Again, in other machines the air has been directly admitted into the casing C or live air chamber, whereas with the "Little Giant" drill it is carried through a separate channel from the supply pipe A, and through a stationary or fixed hollow crank-shaft B, into a passage L, leading to the reduced portions of the piston slide-valves E, and according to the position of such valves admitted to, or exhausted from the cylinders F. It will also be noticed that in the "Little Giant" drill the exhaust does not blow through the gear mechanism, since it is so arranged that it is admitted into the main casing C, which is itself hermetically sealed from the lower portion of the machine which contains the reducing gear, so that the exhaust passes out through a separate pipe K, as shown in the drawing.

The leading feature in the "Little Giant" machine is that it combines a high-speed engine with a low consumption of air, and this result has been obtained by employing a stationary eccentric D, which is set at the required point in the throw of the crank-shaft to obtain the necessary cut-off, the cylinders F, and their governing slide-valves E, rotating about this eccentric. As is well known, in engines of this type the travel of the eccentric should be quickest when the motion of the piston is slowest, and this is provided for in the present design by having a very quick port opening and an equally quick release, thus enabling the rotating cylinders to move at an exceedingly rapid rate, the air not having to travel through tortuous passages either in or out. With other engines of this character, especially with engines of the oscillating type, where the valve motion is slowest when the piston is on the centre or at the end of its stroke this condition does not exist.

The working is as follows:—With the trigger of the throttle-valve in the position shown, the machine is inoperative, the throttle-valve being closed by both air and spring pressure. By depressing the trigger, air is admitted from the supply pipe through A, into the passage leading to the hollow crank-shaft B, along passage L, and through the port opening into the valve chamber and around the neck of valve E. The valve E in Fig. 31 shows the connection as closed between the ports to cylinder F, but if reference be made to Fig. 34 (where for the sake of clearness another cylinder is shown at F^1) it will be seen that the air is coming from the passage L, Fig. 33, up through the port into the recess of valve E^1, and then passing down through the port into the rear of piston G^1, Fig. 32, forcing the same in the direction of the arrow and thereby causing the cylinders to rotate in the direction of the arrow. This action of rotating round the fixed eccentric D, Fig. 34, would cause the valve E shown in section to be moved away from the centre of rotation, or outwards towards the casing C, which would admit air behind the piston G; air would be at the same time exhausting from the rear of the cylinder F^2, Fig. 32, such exhaust air passing from this space up through the same port behind the valve E^2, out through the open end and away through the passage K. The passage L, Fig. 33, above referred to acts as an air-receiver common to the three cylinders. As the machine rotates the same cycle of operations continues.

For results of work done by air-drills, see Table 4, page 147, and page 179.

Other Pneumatic Appliances.—Air-Hoists.

Having put down a system of compressed-air supply for the purpose of driving hammers, drills, and riveters, it soon becomes evident that such supply may be employed for other purposes; and one of the most useful applications that can be made is for working air-hoists. These are now coming into extensive use in this country, and there is every indication that before long few shops will be without them. The economy effected, when they are fitted up on a light jib and suspended over a lathe or other tool, is very considerable, and they save both time and labour. As is well known, much delay is experienced in lowering the ordinary chain blocks, even when unloaded, whilst with an air-hoist this operation is rapidly effected. The load can also be more readily brought into position as the adjustment is very sensitive. Many of the air-hoists in use in this country have come from America, where they have been adopted for some time, but British firms have now commenced to manufacture them, and reference to Fig. 36, Plate 22, shows one of the "Reavell" type. Their construction is simple, consisting mainly of a long cylinder with piston sliding in same; the piston-rod passes through a stuffing-box at the lower end and has fitted to it a hook or loop.

There are also suitable valves for regulating the air-supply and exhaust. The difference between one make of hoist and another lies chiefly in the system of valves and also in respect to the material used for the cylinder. For the latter some makers use cast iron, others wrought iron, and others again use brass. Some hoists have only one valve, this kind being used for quick work and when it is not desired to keep the load accurately suspended for any length of time. This valve is either an ordinary opening and closing valve operated by the hand chain, or it may be a valve to automatically close when the chain is released when either raising or lowering the load. Another type of valve provides for the admission and release of the air in the cylinder, and is left open for supply when lifting the load; working in conjunction with this valve and controlled by the piston-rod is another valve, which automatically closes the air-supply when any desired level is reached: at the same time should there be any leakage of air, it re-admits automatically just sufficient air to maintain the load at a constant level. When however it is desired to maintain in a stationary position a varying load, such as a foundry ladle, a third valve is introduced. Referring to the drawings, Fig. 37, Plate 23, shows a 5-inch diameter hoist with the regulating valve placed at the bottom, length of cylinder being 4 feet 6 inches. Figs. 38 and 39 show the starting cock, and Fig. 40 the lever for a 5-inch hoist. Fig. 41, Plate 24, shows a 7⅛-inch hoist with the valve placed at the top, whilst in addition to this valve there is fitted a small non-return valve to prevent accidents, in case of the air-supply pipe bursting or of reduction in pressure. Figs. 42 to 44, Plate 24, show the safety regulating valve. In the larger hoists this valve is combined for convenience with the main plug of the regulating valve. It will be noticed that there is a small ¼-inch hole near the top of the cylinder; this ensures that the piston shall be brought to rest before touching the cylinder cover, since as soon as the piston passes this port it encloses a certain amount of air and forms an air cushion. The piston is packed with "woodite," as a considerable number of experiments have shown that it is better than leather, since it does not harden, and is consequently less liable to permit leakage. It may be stated that a 5-inch straight lift hoist will lift 10 to 11 cwts.

with 75 lbs. air-pressure. Hoists, such as have been described, may be simply suspended, or they can be mounted on a trolley and light jib for ordinary shop use to serve lathes and other tools. Or again they may serve the whole length of a shop by causing the trolley to run on a fixed over-head girder. The same principle may also be applied for the purpose of lifting in almost every kind of crane, and for foundry and shop use they are likely to have considerable application.

Pneumatic Chain Hoists.—When it is desired to use a chain hoist, for want of head room or length of lift, in preference to a straight lift hoist, and at the same time to obtain a portable power lifting device, this may be secured by using an ordinary chain hoist in combination with a reversible rotary pneumatic motor, Plate 28, such as was described under piston air drills. This form secures a result satisfactory in every way, and effects a considerable saving on hand-lifting.

Pneumatic Jacks.—These may almost be termed inverted hoists. They act on the same principle, and where an air-supply exists they are very useful.

Portable Pneumatic Shears.—Shears of this description are of great service in connection with breaking up ships, boilers, etc., also in repair work, as it becomes possible to shear off rivets and bolt heads, etc., without damage to the plates, as a portable power shears are as light and efficient as anything of their kind. They can be slung from a crane, air-hoist, or any suitable appliance, and readily brought into position. They consist mainly of an air-cylinder and piston operating on a toggle-joint to work the shear blades, and will conveniently deal with bolts, etc., up to 1⅛ inch diameter.

Mining Drills.—The application of the principle of the pneumatic rotary motor for drilling through fire clay, coal and other ores, is likely to meet with considerable success. Piston air-motors such as have been described, with slight modification as to the feeding arrangement, are now being used for mining work, and will drill a 2½-inch hole through 6 feet of coal per minute. They are exceedingly light and easy to handle, and the results so far promise an extended application.

When making comparison of the cost of work between pneumatic tools and hand-labour (and it must be borne in mind that they compete largely with hand-labour), it is necessary to take into consideration three points. (1) That with the same sized shop and the same standing expenses in the form of rent, rates and taxes, and wages bill, a very great deal more work can be turned out in the same time. (2) That although against this there must be set off the cost of producing the compressed air, yet even supposing this equalled the cost of manual labour (which it does not) there would still be a considerable saving for the reason given in item (1). (3) That with hand-labour, especially in riveting, caulking and place drilling, work can only proceed at a comparatively slow rate, however many men be employed, and however closely together they work. This frequently becomes a serious matter in ship and bridge building, railway works, etc., and even were the cost double that of hand-labour, other advantages as regards speed etc. would outweigh it; but, as a matter of fact, when properly carried out the saving is very considerable, and it is in the author's opinion only a question of time, and that not far distant, when every engineering shop will find it absolutely necessary, if it wishes to keep in the van of progress, to adopt the pneumatic, or some similar system of portable tools.

The author is aware that his Paper will lend itself to considerable criticism, because:—(1) He is dealing with a subject which, although a most important one, is yet in comparative infancy; and (2) because there are at present widely different opinions held by engineers as to the advantages of the system; and (3) on account of the very rapid improvements which are being made in the construction and design of the tools, which not only makes it difficult to obtain particulars of the latest types, but renders any data as to their efficiency to become soon unreliable. The makers admit that many of these tools are in a state of transition. There is however, in the author's opinion, a wide future for this class of labour-saving machinery. Notwithstanding however the deficiencies pointed out, the author ventures to hope that the information given and the discussion which it is likely to elicit may be of general interest. He thanks the makers of the various tools for the kind assistance they have so readily afforded him, both in supplying information for the drawings, and for the loan of the tools which are shown at the Meeting.

The author exhibited the following Hammers and Drills, some of which are shown on Plates 11 and 17 :—

Two "Ross" hammers, two sizes of the "Q and C" hammer, and an "Atkinson" (Crossley) tool.

Two "Little Giant" hammers, lent by the International Pneumatic Tool Co., also three "Little Giant" drills; two "Little Giant" tube expanders; two specimens of circular wooden discs 7 inches diameter by $\frac{3}{4}$ inch thick, 1 cut in 50 seconds, the other in 30 seconds by means of a "Little Giant" saw; and six photographs showing several of the above machines at work at the London and North Western Railway Works, Wolverton.

Three "Boyer" hammers, lent by the New Taite Howard Pneumatic Tool Co., also "Boyer" pneumatic holder-up; "Whitelaw" drill; two "Boyer" drills; and "Boyer" pneumatic riveter with pipe-gap frame; the application of some of the "Boyer" tools to ship work was clearly shown by means of two mutoscopes.

Mr. G. J. Churchward of Swindon exhibited several worn parts of pneumatic tools.

Messrs. James Simpson and Co. sent six photographs showing the "Boyer" tools being employed on different kinds of work.

The Paper is illustrated by Plates 11–25, which are taken from the author's drawings and from machinery shown at the Meeting.

TABLE IV.

Results of work done with various types of Pneumatic Tools.

Type of Tool.	Nature of work done, and time taken.	Remarks.	Authority.
Hammer	General	On general work each tool will do the work of two men.	Joseph Adamson and Co., Hyde.
Hammer	Caulking	In caulking, each tool will do the work of three men.	Penman and Co., Glasgow.
Hammers	Caulking	In caulking, each tool will do the work of three skilled hand-caulkers.	Mechan and Sons, Glasgow.
Hammers	Caulking	Two and a half to three times as much work in a given time can be done by these machines as by hand. (Machine caulking is far preferable, as it makes more sound and satisfactory work.)	Edwin Danks and Co., Oldbury.
Hammer	Caulking and Chipping	Useful for both caulking and chipping, doing work for about half the cost of hand-labour, and in most cases making a tighter and better job. Several machines constantly at work.	Clayton, Sons and Co., Hunslet, Leeds.
Hammer	Caulking	In a general way a caulking tool will do as much work as five or six men with ordinary tools, and the work is better done.	Alex. Stephen and Sons, Glasgow.

Type of Tool.	Nature of work done, and time taken.	Remarks.	Authority.
Hammer	Caulking	60 per cent. cheaper than hand-caulking, and quite as efficient. The plates are punished less, and on this account pneumatic caulking is particularly useful for light plate work, such as tenders and tanks.	Mr. James Holden, Great Eastern Ry. Works, Stratford.
Hammer	For cutting off thin steel plates, they have proved very satisfactory, and the work is done in one quarter of the time taken for punching and shearing.	——	Ditto.
Hammer	A chipping 7 inches long and $\frac{3}{8}$ inch thick was cut from a $\frac{1}{2}$-in. steel boiler plate in 58 seconds.	——	The author.
Hammer	It is stated that when using a pneumatic caulker, one man can completely caulk in one day a marine boiler 14 ft. 6 in. diameter, having plates $1\frac{1}{2}$ in. and $1\frac{3}{8}$ in. thick and tested to 360 lbs. per sq. inch.	Another instance is given in which one man caulked in one day inside and out a flue 30 feet long × 2 ft. 9 in. diameter. This previously took 10 days by hand-caulking.	The makers.
Hand Riveter	70 $\frac{7}{8}$-in. diameter rivets can be driven per hour per riveter.	——	The makers.
Stay Riveter	It is stated that they have put in 60 stays, that is, 120 heads, in one hour per riveter.	——	L. & N. W. Ry. Co., Crewe.
Drills	——	Have found them both effective and economical after trial.	Mr. Samuel W. Johnson, Midland Ry. Works, Derby.

Type of Tool.	Nature of work done, and time taken.	Remarks.	Authority.
Drill	Drilling boilers	Very ingenious and useful tool. Can be used anywhere, even through a boiler manhole. Does its work quite as quickly as any radial or other drilling machine, being much quicker than if done by hand.	Clayton, Sons & Co., Hunslet, Leeds.
Drills	When tapping holes in fire-boxes, it takes 36 seconds to pass the tap right through the inside and outside plate, as compared with 1 minute 48 seconds with a flexible shaft.	Until recently, we have exclusively used a flexible shaft for this purpose. This class of work is now seldom done by hand, but would take 5 to 6 minutes to effect the same purpose.	Mr. James Holden, Great Eastern Ry. Works, Stratford.
Drill	As used for drilling work in place a $\frac{7}{8}$-in. diameter hole can be drilled through $\frac{1}{2}$-in. plate in 22 seconds.	This compares by 4 minutes with a flexible shaft, and 10 minutes with a ratchet brace.	Ditto.
Drill	Will drill a 2-in. hole through 3-in. steel in 11 minutes.	——	The makers.
Drill	A hole $1\frac{5}{16}$ in. in diameter was drilled through Bessemer steel 2 ins. thick in $3\frac{1}{2}$ minutes.	——	The author.
Drill	A hole 3 ins. diameter was bored in pitch pine 5 ins. thick in 35 seconds.	——	Ditto.
Drill	54 holes, $\frac{15}{16}$ in. diameter, were drilled in 1 hour 10 minutes, through $\frac{3}{4}$-in. thick end-plate furnace flange of a marine boiler, furnace being in position.	The drill was mounted on a special device which permitted of rapid adjustment of the drill, and also acted as a holder-up. The same work would take $8\frac{1}{2}$ hours if drilled by hand.	The makers.

Type of Tool.	Nature of work done, and time taken.	Remarks.	Authority.
Drill	A small drill drilled a ½-in. hole through 1-in. Bessemer steel in 1 minute 10 seconds, whilst a larger drill will drill 1¼ in. hole through the 1 in. thickness of steel in 1 minute 15 seconds.	—	The makers.
Various	—	Giving very satisfactory results.	L. & N. W. Ry., Crewe.
Various	—	Great saving over hand-labour.	Lumby, Son, and Wood, Halifax.

Discussion on 22nd February.

The Chairman said that the Paper had been necessarily abbreviated, not because it was thought there was too much written in it, or that there was anything in it that was not of great value, but it was really a compliment to the author, because a lengthened discussion was expected. Owing to the abbreviations that had been made, however, it was only fair to give Mr. Amos an opportunity of adding whatever he thought essential to what had been read, either fresh matter, or dealing with some of the paragraphs in the Paper which had not been read, and which he might think it well to read before the discussion commenced.

Mr. Amos said he wished to call attention to a further illustration, Plate 21, which showed the latest type of a three-cylinder high-speed portable pneumatic drill, and possessed several important and novel features in regard to the control and use of the compressed air.

This was a good instance of the difficulty of getting particulars of the latest types, owing to the rapid improvements that were being made. The particulars had been given to him only a few hours previous to that meeting. Further reference to this machine would be made at the next meeting. There was another point on which he should like to give a slight explanation. It would be noticed in the fourth column of Table 3 (page 139), that the revolutions of the drills per minute were given on the machines when unloaded. These machines necessarily ran at different speeds according to the work to be done and the amount of air admitted, and therefore he considered it advisable to give the speeds when the machines were unloaded, although of course they did not work unloaded, and perhaps it was a little misleading. Some of the speeds given were very high, and would not be suitable to drilling holes even of the smallest diameter mentioned. There were some other drills not enumerated in the Table, one of which, a "Little Giant" type, ran at 1,400 revolutions per minute. The speed of a drill however was not necessarily an indication of its power or of its efficiency. There were a number of samples on the table which he believed represented pretty nearly every type of machine at present available for use. Anything else he might have to say could well be left till after the discussion.

The SECRETARY called attention to two diagrams on the wall, showing Mr. Macfarlane Gray's portable riveter with its piston flying backwards and forwards working a tappet-valve instead of a port-valve; it illustrated a Paper read by Mr. Andrew Wyllie* before the Institution. Another diagram, Fig. 51, Plate 26, showed Dunlop's pneumatic riveter made and used at Gorton Foundry. It had been sent by a member at the Foundry, where the inventor was employed.

Mr. J. MACFARLANE GRAY said that he had read with peculiar interest the Paper on Pneumatic Tools, having himself invented a

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* Proceedings 1865, page 129.

(Mr. J. Macfarlane Gray.)

portable riveter, caulker, and chipper, which was operated by steam but more usually by compressed-air, thirty-seven years ago. The distinguishing feature in that early instrument was the "inside blow," continued in the pneumatic-hammers described in the present Paper. His invention was described in Mr. Andrew Wyllie's Paper,* and it was exhibited at work, riveting and chipping, at the Conversazione of the Institution in the Dublin Exhibition. About thirty of these riveters were made. They were not practically successful; the tool head would not stand for any proper length of time. He now recognised that the fault lay in having the stroke too long. This is the only explanation of the success of the new instruments and the failure of his earlier experiments.

He was delighted to have the present opportunity of expressing his unbounded admiration of every improvement in these now perfect instruments. His only claim was his right to appreciate success where he had failed.

What led him to invent the riveter was a statement in a daily paper which, translated into the figures of the present time, would be that one ton of coal used in a steam-engine is more than the muscular equivalent of any British workman for ten years. It is this fact which still eminently justifies the expectations of the ultimate successful introduction of these substitutes for manual power.

Mr. SAMUEL W. JOHNSON, Past-President, said that as Mr. Amos had referred to him in the Paper as having used some pneumatic drills, he had much pleasure in stating that he appreciated them greatly. He had found them of the greatest service in locomotive work; for instance, in taking the copper stays out of fire-boxes, when they were broken or damaged. The "Boyer" drill, particularly Plate 20, was the one he had tried. A man could go inside the fire-boxes with one of those drills, and could cut out most of the copper stays. The drill replaced hand drilling, and the difference could be imagined when he stated that with a "Boyer" drill a copper stay could be taken out in a very few minutes. With regard to pneumatic caulking, tools had been used with great advantage, especially in the seams of boilers, and also for fettling, chipping, and rough-dressing steel wheel castings. He had great pleasure in bearing testimony to the value of these tools as used in the works of his company. He thought there was a very great future for all kinds of pneumatic hammers, drills, and caulkers. He was not quite sure with regard to pneumatic riveters, except as applied to light work. There might be a field for them, but in his opinion certainly not in making locomotive boilers. He had expected that evening to hear from the various makers something of the relative advantages or disadvantages of the different kinds of pneumatic appliances that were being exhibited, but perhaps something would be said about them at the next meeting.

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* Proceedings 1865, page 129.

Mr. T. HURRY RICHES, Vice-President, said that fearing he might possibly not be able to attend the next meeting, he would trouble the members with one or two remarks. First of all he might say that a very amusing incident of his early life was brought to his recollection when he heard his friend Mr. Macfarlane Gray describe the Wyllie steam-riveter. When he first had charge of works in the early part of 1869, finding one of those riveters there, like most young men he wished to know all about it, and he at once proceeded to put the tool into operation, and acquired the information that it took three men to hold up the dolly. One man tried, and he got knocked down. He himself gave it up. With regard to pneumatic-caulking and drilling machines, he thought he had tried nearly all the samples exhibited at one time or another, and had found certainly one feature that was worthy of very careful consideration, namely, the effect of vibration in holding up the tools to their works. They had now been constantly in use for some years, every day, and the tool that had been found to give the best result was the one with a hook handle, as distinct from other classes of handle. The vibration from the ring handles had been found to be very severe to the men, and he had constantly had serious complaints from the men when they were doing heavy work.

(Mr. T. Hurry Riches.)

especially on caulking steel-plates, that the vibration very materially affected them ; whereas with the former machines, although using the same pressure of air and doing the same work in the same time, the effect was nothing like so severe, and certainly did not tire the men to anything approaching the same extent. He hoped to send to the next meeting the result of a very considerable number of experiments which he had tried with various tools with regard to the consumption of air and the work done. As far as the drills were concerned, he might state that he had not been content to take the speed of revolution, but he had found out how long it would take to drill a given-size hole through a given depth of material in a given time, and how much air it took to do it with pneumatic-drills of various kinds; and in that way he found there was as much as twenty-five per cent. difference in the consumption of air to drill the same hole through the same material and to the same depth. That was information which might be found useful, and he should be extremely glad to send it to the Secretary for publication in the Proceedings, if he was not able to attend the next meeting. He had tried the tube-expander upon the pneumatic-drill spindle with the "Stow" flexible shaft, and for heavy tubes he found them work very well, but for light tubes they were not a success. So far as tapping was concerned, he was bound to say he thought the pneumatic-drills were a vast improvement upon hydraulic machinery, and for the reason that the size of the drill could be varied, and of course the power would be varied from the fact that the resistance in front of the pistons was reduced with a smaller hole. Consequently the consumption of air was less as compared with using water. The same quantity of water would be used to drive the machines with a small drill as to drive a machine with a large one. [See page 176.]

Discussion on 22nd March.

The CHAIRMAN, in re-opening the Discussion, said that Mr. Macfarlane Gray had narrated an interesting historical note upon the subject (page 152). Many years ago Mr. Gray had been struck with the barbarous system of riveting with a striking hammer and dolly, and he had designed a pneumatic riveter, for which he had taken out a patent, of which he showed the drawings. He said that the reason the machine never came to any good was simply because they could not temper steel so as to make it withstand the constant impact of the ram against the head of the chisel. Mr. Gray mentioned that the tools that were exhibited were very beautiful improvements upon what he had unsuccessfully essayed so many years ago.

Mr. C. LIDDELL SIMPSON said that with regard to pneumatic drills, his experience had been almost entirely confined to the "Boyer" drill. He had placed some photographs on the wall. Fig. 53, Plate 27, showed a "Boyer" hammer chipping fins in a brass foundry, where it was found to be a very convenient tool, and the men themselves had taken to it quite recently. Another photo shown was an application of the "Boyer" casting cleaner, fixed on a bench, to which was attached an emery wheel. In his works there was another application of compressed air, namely, with a "Tabor" moulding machine, which had a rapid attachment, and worked equally satisfactorily. It was found that in the brass foundry there was great saving in using pneumatic chippers for cleaning castings. Another photo showed a trimmer using a chipping-hammer in the iron foundry, where he had had some trouble, as the trimmers had not taken to it readily, because, as they said, it jarred them. It was only the younger men who had been persuaded to use the tools, which however worked well, and he thought in the course of time their number would be increased. There was a photo showing also the application of one of the "Boyer" piston-drills, used as a portable drill dealing with a heavy

(Mr. C. Liddell Simpson.)

pump-casting in the middle of the shop. It had been found a very great convenience, and the compressed air or piston-hammer worked much quicker than the drill driven with the "Stow" flexible shaft, or any ratchet. A drill of that description very soon paid for its initial outlay. He had on hand at the present time a deep well job, where compressed-air had been taken down 200 feet, and the machine was drilling the tapping holes to hold the girders in the well. A couple of Westinghouse air-compressors were rigged up, some of the pump-delivery pipes being coupled up to make an air-receiver, and that had enabled them to do the job very much more rapidly than would have been the case otherwise. The next application was the small breast drills, which were found very useful for drilling small holes for fitting lagging on cylinders, or small holes on a long rod, or a piece of work which was not so readily put underneath the drilling-machines. As far as his firm had gone with those drills and pneumatic tools, they had not had much trouble with them, but of course it would be a question of time to know how they "panned out" for repairs and renewals, or whether they would really prove a success over a number of years. As far as he had gone he was perfectly satisfied with them. He had also tried air-hoists, which were mentioned in the Paper, and found them very useful, especially in foundry work, or, as shown, arranged over a lathe for lifting work rapidly. Another photograph showed the application of compressed air to a whitewashing machine for spraying whitewash over walls, and it had been found a very useful implement. As far as his firm had experience with the use of pneumatic tools, he thought that before very long they would have to increase the number.

The CHAIRMAN said that at the Great Northern locomotive works at Doncaster he had had the pleasure of seeing the best and most extensive use of pneumatic power that he had seen anywhere. The Institution had the advantage of Mr. Ivatt's presence that evening, and he would request him to give the meeting his views upon the subject.

Mr. H. A. IVATT, Member of Council, said they had gone in at Doncaster pretty largely for pneumatic tools; but he did not intend to occupy the meeting with a scientific discussion as to the action of the various hammers, nor had he any data as to the consumption of air. They had been so busy at Doncaster that there had been no time to make experiments on air consumption, &c. They knew the system was a good one, and that was the reason they had extended it The erecting-shops, the carriage-lifting shop, and some of the machine shops were piped for air all the way round. The pressure at which they worked was 80 lbs.; belt-driven compressors of the two-stage type were used, the smaller sizes delivering about 40 cubic feet and the larger machines about 100 feet each of free air per minute. In fixing the compressors there was one small point which it was worth while to bear in mind, namely, that it was advisable to get the air that came into the compressor as cold as possible. If the air could be obtained a few degrees colder than that in the immediate neighbourhood of the compressor, by running a wood trunk to the north side of the shop, or down into the cellar, it was worth while doing so. The colder the air, the more was got into the cylinder ready for compressing on the return stroke. If the air-delivery pipe was run straight up from the compressor, and then downhill towards the first receiver, that receiver would catch all the water, and there would not be trouble with water in the pipes round the rest of the shop.

At Doncaster they used some of the drills that had been described. He thought the largest number of drills were of the "Bradford" type, Fig. 52, Plate 27. It had no cylinders, and for drilling stays and work of that sort the drill was found to be very suitable. It was also used for tapping stay-holes in boilers, and for that work the drill was fitted with a reversing arrangement. There were in use at Doncaster four or five different sorts of hammers for chipping, caulking, &c. He had not yet had an opportunity of trying the long-stroke hammer. In selecting a pneumatic hammer, preference should be given to one that gives as little vibration as possible. They also used air-engines for boring out the cylinders of locomotives under repair, and for facing the valves. Those little

(Mr. H. A. Ivatt.)

engines were similar to ordinary small steam-engines with cylinders about 4 inches by 4 inches and the valves of the piston type, with the valve-chest open at each end. When used to bore cylinders the engines were simply clamped on to the outside frame of the locomotive, and the belt from the fly-wheel of the little engine was led to the driving pulley of the boring machine by a pulley. For facing the steam-ports the little engine stood up on end, and drove the pulley on the end of the port facing machine. There were one or two other uses to which compressed air was put at Doncaster, which might possibly interest members. A whitewashing plant was fitted up on a railway truck, with a small engine and boiler complete, and an air-jet was thus used for whitewashing sheds and other buildings. An attempt had been made to clean carriage cushions with compressed-air, but so far without very satisfactory results. The instrument used was something like a curry-comb; the jet of compressed-air induced a partial vacuum at the face of the "comb" as it was passed over the cushions, and delivered the dust through a tail-pipe into a bucket of water outside the compartment. It was very nice to look at, but not fast enough. Compressed-air was also used for "blowing through" locomotive cylinders, and for moving engines out of the shops. The boiler was charged with air from the shop main, and the engine run clear of the shop sidings by compressed-air instead of by steam.

Mr. H. GRAHAM HARRIS, Member of Council, desired to ask two questions. Mr. Ivatt had mentioned the difficulties that he had, and the way he had overcome them, with regard to water in the pipes. He (Mr. Harris) wished to ask, was the air cooled by a direct injection of water into the cylinder, or done by a water-jacket?

Mr. IVATT: A water-jacket.

Mr. H. GRAHAM HARRIS said that then he could not understand why there was difficulty in getting rid of the water in the air. The mode Mr. Ivatt had used was adopted even in those cases where the water was injected into the cylinders, where higher pressures up to 450 lbs. were successfully employed.

His second question related to cleaning cushions. Had there been a serious attempt to use compressed-air for this purpose, or was it only an experiment? One could not imagine that the mode was likely to be successful, inasmuch as it could only have removed the dust from the surface of the cloth, or whatever the cushions were covered with, and could not have taken out that which was embedded in their thickness.

Mr. JOHN FIELDING said that he had used compressed air with advantage for drilling and chipping, and had found it better than the "Stow" flexible shaft. He considered that there was a future for pneumatic riveting under certain conditions, and that it would replace a good deal of hand-riveting. It would not, however, supersede hydraulic riveting, which, in the majority of cases, was much to be preferred, especially for boilers and the heavier class of riveting generally. He was much interested in the various examples of pneumatic hammers described in the Paper, having himself made one or two pneumatic caulking-machines some twenty-five years ago. One of these machines, which was most successfully used in the year 1876, was illustrated in Fig. 49, Plate 26. This tool, it would be seen, differed in no essential respect from the modern machines. It moreover possessed a feature not present in any of the later tools, namely, a spring tool socket by means of which the weight of blow delivered could be regulated according to the force with which the tool was pressed against the work by the hand of the operator. The spring arrangement also tended to reduce the vibration upon the hand. He had not, however, followed up the invention, because he was at the time much occupied with the development of hydraulic machinery, and moreover it was then thought by many that with the new system of riveting all necessity for caulking would be done away. Experience had, however, shown that there was still room for the use of a caulking tool. He believed that the caulking machines he had made were the first of their kind ever employed. He would suggest that the air pressure for riveting might with

(Mr. John Fielding.)

advantage be increased to 100 lbs. per square inch, as in that way the weight and bulk of the machines might be reduced. He would like to hear from those who had used both kinds, whether the double-stage compressor had not, in practice, advantages over the single-stage compressor.

Mr. AMOS, replying to Mr. Fielding, said that the pressure used at the London and North Western Railway Carriage Works was 100 to 120 lbs. to the square inch. In some cases they were reducing this where necessary, but he believed they were working their hammers at that pressure. The double-stage compressor possessed undoubted advantages over one of single-stage compression, when the pressure exceeded 80 lbs., since it permitted cooling the air after the first stage and before final compression, and the resultant temperature was much lower than when compressed from atmospheric pressure to the final pressure in one cylinder.

Mr. BENJAMIN MARTELL said he had great pleasure in making a few remarks on the Paper, because he thought it one of enormous interest at the present time. As he had served some thirty years as the chief surveyor of Lloyds' Register, he had come in contact with a very large number of shipbuilders and engineers, who were looking forward to some means of substituting pneumatic tools for manual labour for many purposes. The members did not need him to explain the enormous difficulties that the employers of labour had at the present time in dealing with the labour market; and he saw no way for shipbuilders and engineers being able to ensure constant and economical work by the former methods. He did not care how work was performed, whether by machines or by manual labour; it had not been his duty to supervise that. He had no hesitation in saying that pneumatic tools could produce the soundest work. He had seen the tools in operation, he had seen the $\frac{7}{8}$-inch rivets driven by the "Boyer" hammer, and had had the plates slotted through, so that it could be seen how the rivets were laid up and filled the holes. He had assured himself that it could be done. In the next place the rapidity with which the work could be done, as compared with manual labour, had to be considered. By doing the work rapidly there was an enormous saving in the expense. Then if rapid and constant work could be guaranteed, that was a great advantage to employers who could ensure themselves being able to complete the contracts in the time calculated and contracted for. Another very important matter was the expense. Mr. Badcock, in a letter written to Mr. Cramp of Philadelphia, who was extensively using pneumatic tools, had written: "As I understand that you have finally made a start on the pneumatic riveting, probably some figures I have just had made up as to the results of the work with those tools in our yard for the last three weeks will be interesting. I therefore enclose a statement of rivets driven during the three weeks ending 12th October, from which you will see that with a total of over 95,000 rivets the average cost of the machine-driven rivet is only $\frac{1}{4}$ cent against 3·19 cents, which would have been the cost if those rivets had been driven in the old way by hand. . . . This makes an average saving per minute of 1·09 cent, making the average cost of machine rivets only 47 per cent. of the hand cost, or a saving on each ship of the class we ordinarily build of from 5,000 to 6,000 dollars on one ship. Of course you cannot expect at the start to make such a saving as this, but I see no reason why in a comparatively short time results equally as good may not be obtained in your yard. It does not take much except ordinary common sense and plenty of compressed air to handle these machines." He, Mr. Martell, thought that was very satisfactory indeed. He thought it was rather to be regretted that Mr. Amos had given no data with reference to the "Little Giant" machine. It was not known what that machine had done, and all the data given in the Paper were obtained from the work of the "Boyer" machine.

Mr. W. W. MARRINER said that through the courtesy of Mr. Yarrow he was able to give the results of the experience with portable pneumatic tools as they had been used at Poplar. The pneumatic hammers were used for a great variety of purposes, such as bell-mouthing tubes, chipping propellers, and caulking. Several types of hammers had been tried, and the type which was preferred

(Mr. W. W. Marriner.)

at the present time was the "Boyer" hammer. One reason was that the vibration which was transmitted to the man was so small that there had never been a complaint from any of the workmen using it, and they preferred using that tool to using the old hand-hammer. Another reason was that the little screw at the bottom of the handle was very useful for regulating the weight of blow given by the hammer independently of the trigger, so that in doing very light work the man was not frightened of pushing the trigger too far, and giving a heavy blow, thus spoiling the work. It had been found that the chief points to pay attention to in using these hammers were as follows. Firstly, the hose required to be as light as possible, so as to offer the least resistance to the free movement of the man using the tool, while at the same time it required to be a hose such as was not easily damaged. A good india-rubber hose was preferred to any armoured or metallic hose.

A MEMBER asked what pressure was used with the rubber-hose.

Mr. MARRINER said at Poplar they worked with 100 lbs. pressure. The rubber-hose used had linen insertion. Secondly, the chisels could be ground rather keener than hand-chisels, as the work was done by a number of comparatively small uniform blows, and not by heavy variable blows as with a hand-hammer. Of course the keener the tool the quicker the work was done. Referring to pneumatic drills, these were used for several purposes. They were used on the boats for drilling all sizes of holes; they were also used for drilling awkward pipes that could not be got under the machine, and they were used in the erecting shop, when it was not always convenient to take the work to a machine. They were also tried for expanding boiler-tubes, with our special self-feeding expander, but without much success. Of course he was referring to the "Boyer" drill, which was the one most commonly used. The reason it would not work, as was pointed out by his friend Mr. Crush, was that it went too fast, and that in using an expander the pressure required was very much greater just at the finish than at the beginning. Another requirement was, that to get an expander out of a hole it had to be reversed a turn or two, and the "Boyer" drill did not reverse. The matter was taken in hand, and besides a reducing gear a reversing gear was fitted in the drill-handle, so that the man never had to let go the two handles of the drill, since which he did not know of a more convenient tool for the purpose of expanding tubes. At Poplar they also had in use a great many useful pneumatic hoists over the heavy machines. The only drawback to these hoists was that at first, until the men got used to the operating valve, they were just a little too quick.

At the last meeting the Chairman (page 106) had invited a comparison between portable pneumatic tools and electrically-driven tools, and as Mr. Yarrow had put in both installations about the same time, there had been an opportunity of making that comparison. In making a comparison there were distinct uses for which each machine was quite superior. For instance, if power was required in the shape of a blow, then obviously compressed air was the best; but if it was required to drive a machine above 1 H.P., and at some distance away from the source of its work, then electricity was better. To make his meaning clear, and to show that there were some fields in which both systems were rivals, he should like to draw attention to some fundamental points in connection with the two systems. To begin with, the pneumatic drill was self-contained, that was, the drill was direct on the machine, while, except in the case of very small electric motors, it was necessary to use a flexible shaft. Also, an electric motor was very much heavier than a compressed-air drill for the same power; but if a flexible shaft was used, the drill was very much lighter than the pneumatic drill, and consequently it was much easier to set up over the work to be drilled. Then again a compressed-air drill might be reversed with impunity, which is not the case with a flexible shaft and electric motor. Another thing about electricity was that a cable could be put where perhaps a pipe line might be in the way. He would take an example or two of the work at Poplar, where sometimes a choice had to be made between the two systems. If in the deck of a boat they had to drill large ventilator-holes, and the small holes for the flange of the ventilator, then they would use electricity, which could be very easily carried

(Mr. W. W. Marriner.)

from one end of the ship to the other, and the flexible shaft could be easily connected to the boring power for making the large holes, and then to the little drill for making the small ones. In expanding boiler-tubes, compressed air would be used, because it was self-contained and there was no flexible shaft to get in the way of the man, and at the same time it was reversible, which the flexible shaft was not. If small vertical holes were being drilled in the deck of a boat, then the electric motor was used, because the weight of the motor helped to push the drill through ; but in drilling small holes for cylinder lagging, or bulk-heads, little holes about $\frac{1}{4}$ inch, then compressed air would be used, because the man could hold up the small breast-drill where it would be impossible to hold up the electric motor. So it would be seen that every case required careful study of the circumstances, and it was best to have both systems. In conclusion he expressed his feeling of gratitude to the author for bringing so valuable a Paper before the Institution, and he was quite assured that if any member put the system into his works, he would wonder in a few months' time how he had got on without it, and he would more fully appreciate the Paper than perhaps he did now.

Mr. William Schönheyder asked Mr. Martell, whether in the particulars he gave for riveting by compressed air, he included the cost of the plant and the compressed air, and interest on depreciation.

Mr. Martell said the whole cost was included.

Mr. J. W. Duntley, President of the Chicago Pneumatic Tool Co., said he had started in business about five years ago, and had sold during the first year about 100 pneumatic tools. To show the success of air-tools in America, last year he had sold over 800 tools per month, which, he thought, was the best argument he could give that air-tools were a success. Messrs. Cramp's ship-yards of Philadelphia had today over 300 air-tools and were now putting down compressors to furnish 17,000 cubic feet of free air per minute ; they were paying 35,000 dollars for the piping of their yards, and had just won a strike over 7,000 men, who went out about two months ago on account of the use of the long-stroke hammer. That yard was launching this month a steamer in which the rivets in the entire ship had been driven by pneumatic hammers and shell riveters, and Messrs. Cramp did not intend in future to drive any more hand-driven rivets. The Russian Navy yards were about to put down a large number of air-tools; and the inspector informed him that the machine-work was so superior to hand-work that it would only be a short time before the European shipowners would ask all shipbuilders to use pneumatic riveting. It required a rivet one-eighth of an inch longer to drive with a pneumatic hammer than to drive it by hand, and the riveting was very much superior, as the hole was entirely filled up. In removing a faulty hand-driven rivet from a ship the head was cut off, and by giving it a blow the rivet flew out. In removing a rivet driven with a pneumatic hammer, after the head was cut off it was necessary to drill the rivet out. Taking any plant in a boilermaker's shop today, either in Europe or America, he would himself take the long-stroke hammer, and drive a better rivet than could be driven by hydraulic power. In Germany he had won in a test with the machine against hydraulic power. In Chicago they had recently had a strike of all the boilermakers, some thirty boiler shops being out. The machine was put on the market about that time, three months ago, and every hand-driven rivet today in the high-pressure boilers in those shops was driven with a pneumatic hammer. He thought that every firm of importance in America was using the tools, and those firms would endorse this statement. Also 97 per cent. of the railroads in America today were using pneumatic tools and drills, wood-boring, and painting machinery, and doing every class of work that a railroad had to do by compressed air. Breaking stay-bolts and that class of work was now practically entirely done by air-tools, which also effected great saving in flue cutting. In taking out old tubes they were cut just inside the sheet, all ready for scarfing. In putting in new tubes with the same machine the tubes were all cut in position outside the sheet, just ready to be turned over, instead of having to measure the tubes and carry them backward and forward. If the front

(Mr. J. W. Duntley.)

of the boiler was in any way sprung, the cutting could be done as the tubes were put in. In the Government shipyards scaling boilers was being done with a wide chisel put into a small hammer. There were 120 machines in one Government yard.

The CHAIRMAN asked if, in breaking up an old ship, the heads were knocked off.

Mr. DUNTLEY said there was an arrangement of a biter for that work. In the railroad shops a biter was used for biting off stay-bolts, and in destroying old ships the heads were bitten off instead of being cut off. It was very difficult to cut them off on account of the rust. If any member would like to ask questions upon any point he would be pleased to answer them, and give further facts relating to the subject, because he did not think there was any style of work in America today but what was being done with air-tools. Almost daily some new application of air-tools came up. A freight car in America was now painted in seven minutes by compressed-air, trucks and all. His firm had recently brought out a machine for burning varnish off the passenger cars, and similar work. Nearly all the stone work, as for instance the carving of the Grant Monument, was done by air-tools. They saved nine dollars a day over hand-work with each tool. They also had a hand-rammer for pit work in foundries, which did the work of twenty-two men. There were today about seventy or eighty different styles of air-tools, and he felt certain that inside of two or three years in Europe it would be the same, and air-tools would be used here as extensively as they were in America. Five years ago they had experienced probably a worse time than this country was going through now, because they had to educate the people to use the tools. This year he had met in America a great many European gentlemen, and in some cases he had taken them to visit works, where they had been surprised to see the different tools at work. That had assisted the introduction of the tools into this country.

Mr. G. J. Churchward wished to ask Mr. Duntley one question about the stay-bolt biter, the machine for biting off the heads of the rivets in the stay-bolts. He was personally rather more interested in that machine than any other air-tool he knew of. He possessed one of those stay-bolt biters, or rather a machine with a claw for clipping off the rivet-heads, and was sorry he was unable to make it bite.

Mr. Duntley said that the machine was made for stay-bolt work, and bit off the heads square. It was necessary to bend the claws, so that they had a tendency to bite in.

Mr. G. J. Churchward showed a few worn parts from the pneumatic tools which were used at Swindon, and said he thought it would probably be interesting to the members to have an opportunity of seeing the parts that were worn out, in order that their ingenuity might be exercised in improving them. From a very considerable experience of air-tools at Swindon, he had come to the conclusion that the only thing required to make them perfectly successful was to greatly improve the working parts, in order that they might last longer. They did not complain very much about the wearing out of the tools, because they were subjected to such a large amount of work, and saved so large an amount of time and money whilst they were at work, that even with necessary repairs it was worth while to use them. Improvements had occurred to him as being possible in several directions. One difficulty occurred with the vibration of the hammer. In the boiler shop of the Great Western Railway at Swindon a very large amount of riveting, chipping, and caulking was going on; the vibration was very annoying, and when pneumatic tools were first used there for caulking, considerable trouble was experienced with the men, in fact the shop was so noisy that it was scarcely possible to live in it. A great amount of that trouble was got over by putting round the boiler-barrels, when they were being caulked, a wide strip of leather, preferably an old driving-belt, which was hooked on to a neighbouring column or anything handy. Small accidents occurred more or less frequently with the tools

(Mr. G. J. Churchward.)

dropping out in the men's hands when the pressure was put on; and if the gentlemen who designed or made these tools could devise anything which would prevent such a trifling though annoying accident, a further advantage would be gained. Then it had been found necessary in using some patterns of drills to put a shield against the exhaust-air outlet, because in using them for some time on end the men's hands became numbed by the exhaust-air. He was glad to hear a reference made by one of the speakers to the flexible pipes, because that was also a trouble. The flexible pipes which they used at Swindon were very heavy and cumbersome, and he was sorry to say a great deal of leakage went on at the joints. What was wanted was a really first-class light flexible hose, with joints which would never leak under any circumstances. He was very pleased to hear a reference to tube cutting, because at Swindon they had never succeeded in properly cutting the tubes out of a boiler by a machine. The ideal way to do it was to put a small saw or cutter inside the tubes, through the ferrules if they were used, cut the tubes off, drop them all down, and pass them out of the barrel. At first some little trouble had been experienced with tube rolling, but at the present time the expanding of tubes in the tube-plates was being done quite successfully. He agreed with Mr. Marriner (page 164) that pneumatic tools were quite the best for making a sound tube in a tube plate. Another great desideratum was a stronger hammer. At Swindon they had tried the new long-stroke hammer, and found it very much superior to the older and shorter form. Work which was found quite impossible with the other hammers could be done with it. In boiler repair work, in which the field for pneumatic tools was very large indeed, there was an immense amount of cutting off of stay-heads and rivet-heads, which was hard and laborious work for the men, and expensive when done in the usual manner by hand. He required a rather heavier hammer with which a man could go along and shear off rivet-heads in about five seconds each. With the long-stroke hammer copper stay-heads could be cut off, and although he was not in a position to say definitely what time it would take when the men got accustomed to the tool, he could say that the men could go across a fire-box at the rate of about fifteen seconds a head. If a tool could be obtained which would tackle steel rivets in the same way, he for one should be very pleased. If he might give a word of advice, he would say that it was necessary to commence on a large enough scale. At Swindon one of their principal troubles lay in the fact that their mains were too small, the compressors were inadequate, and they could double or treble the use of air-tools in the shops, if there was enough air. He did not think sufficient note of the cost of compressing the air had been taken in the estimates which had been frequently given for doing the work.

The CHAIRMAN asked what pressure of air was used at Swindon?

Mr. CHURCHWARD said it was 80 lbs., but he thought it would be better in future to use 100 lbs. If the pressure could be obtained by the use of some waste power, there would be a "gold mine" in the pneumatic-tool system. At Swindon about three locomotives a day were tested, and a plant was now in course of construction for testing these locomotives on rollers, instead of running them about the line. That was done, as the members were aware, on the Chicago and North Western Railway, and also at the Purdue University, Indiana, but at Swindon it was proposed in addition to utilise the power of each locomotive in pumping compressed-air for use in the shops by driving compressors off the roller shafts, upon which the driving-wheels of the locomotive would run. By that means they expected to get a certain amount of power very cheaply.

Mr. ALFRED HANSSEN said that, having had considerable experience with pneumatic machinery, he wished to make a few suggestions. First, with regard to wear and tear of the pneumatic tools. He had noticed that compressed-air contained a good deal of grit and dust; he had held his hand in front of a jet of air and found this grit sharp enough to draw blood from the hand. Naturally such grit would wear out the working parts, both of air-compressors and of air-driven machinery. The remedy was to

(Mr. Alfred Hanssen.)

filter the air before compression. This could be readily done by passing it through a wet screen, a wet coke-filter, or by washing it in a scrubber. His second suggestion was with regard to the economy of working the tools. Complaints had been made of the low efficiency of pneumatic transmission. The reason for this was that a great part of the work of the air-compressing engine was being converted into heat, and as the air was used cold and non-expansively in the tools all this heat was lost. When working with an air-pressure of 100 lbs. per square inch, and exhausting into the atmosphere, it was impossible to get a higher efficiency than about 28 per cent., counting from the indicated power in the steam cylinder to the indicated power in the working cylinder of the tool. The loss of power was therefore 72 per cent. This loss could however be materially reduced by working with a closed circuit, using a return main in the same way as it was used for hydraulic and electric motors. The loss of power due to heating is not dependent upon the working pressure used in the tools, but upon the ratio of compression, that is, the quotient of the higher pressure divided by the lower. Working with air of 100 lbs. pressure, and exhausting into the atmosphere, this quotient is $115 \div 15 =$ over 7, but working with a closed circuit, the lower pressure might be kept at 100 lbs. per square inch, and the upper pressure at 200 lbs.; this would still give an effective working pressure of 100 lbs. per square inch, but the ratio of compression instead of being over 7 would be reduced to $215 \div 115 =$ less than 2. He therefore recommended that the air-compressor should draw air from a low-pressure air-receiver, where the pressure was 100 lbs. per square inch, and discharge it into a high-pressure air-receiver at 200 lbs. per square inch, and that the pneumatic tools should draw their air-supply from the high-pressure air-receiver and exhaust into the low-pressure air-receiver through a return-main. The compressed air would then be used over and over again. This system had been used successfully in some American mines, but did not appear to be generally known. It involved some additional complications in the mains, but working in the manner described, it was possible to raise the efficiency from 28 to 53 per cent., and the working expenses could then be reduced nearly to one-half without making any alterations in the tools themselves. He thought that this matter was well worth the consideration of those who intended to introduce pneumatic tools into their workshops.

The Chairman thought the members would not be surprised that he rose to close the discussion, especially as the notice had led them to expect an interesting Paper by Mr. Bryan Donkin on the Steam Revealer. He was of opinion that the Institution must mend its ways, and not go on indefinitely into the evening, as he thought it was far better that the members should come to the meetings knowing within reasonable limits when they might expect to be set at liberty. He must therefore close the discussion, which he thought had been very satisfactory. Still if there were any members who felt that there were omissions in the discussion, and would send up any remarks in writing, the Secretary would be glad to receive them, and to add them to the record in the Proceedings.

Mr. Amos, in replying, said there appeared to be a consensus of opinion that the pneumatic tool was going to play a very important part in engineering industry. He himself had been so firmly convinced of this that he had devoted considerable attention to the question for some time past, and had thoroughly investigated the question before presenting this Paper to the Institution. He believed that this was the first occasion the subject had been dealt so with in this country, and he had to thank the members for the kind manner in which they had showed their appreciation of his efforts. He had treated the subject so exhaustively in his Paper that it was unnecessary to make a lengthy reply. He might say that, whilst two types of tools appeared to give more satisfaction than those of older design, he had studiously avoided making any unfair comparisons. With regard to Mr. Martell's remarks (page 161) as to the work done in the Chicago ship-yards in respect to riveting, these identical particulars were given very fully in the Paper (page 136). The reason why the "Boyer" tools were better known here than the "Little Giant" was because the latter had only just entered into this

(Mr. Amos.)

country, where they were now being manufactured. The question of different air-pressures for working the tools was, he thought, an exceedingly important and interesting one. His experience so far had led him to believe that according to the class of work that was being done, a variable pressure would be required. For riveting work, undoubtedly a higher pressure was required than for most other classes of work. For hammers he considered from 80 to 100 lbs. most suitable, and for drill work a rather lower pressure could be economically used, except where the work was very heavy. So long as joints could be maintained and leakage avoided, high pressures were to be generally recommended, and it might be found convenient to start with 100 to 120 lbs. or even more on the mains; it was occasionally reduced according to the machines that were being served. He thanked the members for the kind way in which they had received his Paper.

Communications.

Mr. JAMES ATKINSON, in sending working drawings of two pneumatic-hammers which had been made at Messrs. Crossley Brothers' works, wrote that the hammer shown in Figs. 46 and 47, Plate 25, was the type of tool manufactured some years ago. It showed the latest arrangement of the tool; but in a somewhat similar form it was really the pioneer of the pneumatic tool, and a considerable number of them were made. It worked very satisfactorily when in proper condition. Like most inventions in their early stages, it was somewhat complicated, the piston itself being a most expensive piece to manufacture; also the slide-valve, being placed in the piston, was subject to serious side strains due to its inertia, causing rather more rapid wear than would otherwise have taken place, though the most serious fault was due to so much of the substance of the piston being cut away at this one part, causing local weakness and in many cases fracture. These considerations led to the abandonment of its manufacture and to the substitution of a more simple type, as shown in Fig. 50, Plate 26, in which the air-pressure was always upon the annular space, giving a constant pressure to return the piston. As on this return stroke the little holes open to the annular space, air is admitted to the head of the piston, and the blow is struck. These pneumatic tools have been made with short strokes for rapid blows, and with longer strokes for heavier work. Some of the tools have been run at over 30,000 blows per minute, and the working of the tool generally has been most satisfactory.

Messrs. Beyer, Peacock and Co. sent a drawing of a valveless pneumatic-hammer, from which Fig. 51, Plate 26, has been prepared. They wrote that this pneumatic-hammer was invented and patented by Mr. James Dunlop, now in their employ. It was nearly two years since they first commenced using it, and the fact that the hammer was preferred by the workmen speaks well of it as regards the questions of power and small vibration, in view of the fact that piece-work rates were paid, and that hammers by other makers were at hand ready for use if preferred. There was only one moving part, namely, the differential piston, which acted as its own distribution valve, and struck the tool held in the socket at the front end of the hammer. The trigger in the handle was moved by the thumb to start or stop the hammer, the form of the little valve being such that a considerable variation in the intensity of blow and the speed of the hammer was obtained. On tracing the course of the air, it would be seen that a constant pressure was exerted on the annular area of the piston to move it in the direction of the handle. At a certain period of this movement the inner set of cross-holes in the piston were drawn into the annular space, and air-pressure passed to the back of the piston, where acting on the whole area the piston was driven forward to strike the tool. At a certain period of this forward movement the outer set of cross-holes in the piston passed into the chamber at the front end of the hammer, when exhaust took place, the inner set of cross-holes in the meantime having passed the edge of the annular space, thereby being shut off from air-pressure. One feature of this hammer was the high rate of speed at which it worked in comparison with many of the other hammers on the market. The first hammer of this type had been used in Messrs. Humphrys Tennant and Co.'s works in 1895.

Mr. JAMES DUNLOP wrote that the first differential-piston valveless hammer known in this country was patented in 1881. Then followed patent No. 2185, 1885. But the first hammer, like the "Ross," had the defect of having a "dead point." He had tried every form of handle, arrangement of ports, &c., in his differential hammer shown in Fig. 51, Plate 26, and as now made he thought it was more efficient than any other he had seen.

Mr. JOHN P. O'DONNELL wrote that he was considerably interested in the manufacture of portable pneumatic tools, but had refrained from speaking at the meeting because he thought that the discussion should be left to those who were users of the tools and had had practical handling with them. The "Little Giant" tools had been only recently introduced into this country, and were used at Wolverton on the London and North Western Railway and by other railways. But in the United States they were used in 90 per cent. of the shipyards and locomotive shops, and other large industries. During the year 1899, 5,000 pneumatic tools were sold by his company, and the demand was rapidly increasing.

Mr. WILLIAM REAVELL wrote that, beyond the remarks made by Mr. C. L. Simpson (page 156), there had not been much reference made to the great convenience of pneumatic-hoists. He thought that some notes as to his own experience on this point at Ipswich would be of interest to the members. In every machine-shop the question had to be considered how to deal with objects which, although too heavy for handling by the operator himself, were too numerous and too light to be all dealt with by a heavy travelling-crane; and, after comparing the various mechanical aids which might be brought into requisition, they had installed pneumatic-hoists over all the heavier tools, such as lathes, planing machines, boring mills, &c. They had particularly under consideration the handling of articles such as crank-shafts, engine-cylinders, standards, &c., the weights of these articles varying from two or three cwts. to one ton, or thereabouts. One of the hoists is shown on Plate 22. The air-hoist was suspended from a swinging jib, the lower member of which was so arranged as to form a rail, on which the wheel carrying the air-hoist ran. Articles could be lifted in and out of the lathe in about a third of the time required with chain-blocks; but this did not represent by any means the full saving, as the operator on the various machines used the air-hoist himself to deal with his work, whereas with pulley-blocks he used to wait until a labourer was disengaged and could come and supply the "motive power;" and this naturally represented a considerable saving. Pneumatic tools of the "Boyer" type were also used both in the machine shop and erecting shop, and were found to be excellent time-savers.

It was at first feared that the vibration of the hammers would cause some trouble, but instead of this being the case their experience had been that the erectors preferred to use the pneumatic-hammer instead of a hammer and chisel; and, if a hammer was not immediately available, the fitters preferred to go on with another job than use their hammer and chisel, as they could save time and do good work with the pneumatic-chipper. A "bonus" system was in use in the works, which possibly explained the absence of any prejudice against innovations. "Whitelaw" drills were used for centering heavier work for the lathes, such as crank-shafts, &c., and the larger "Boyer" drills were used in the erecting shop for drilling holes in place, &c. In the manufacture of air-hoists a large pneumatic drill was used for drilling the flanges with excellent results, in place of a drilling machine.

Referring to a difficulty which had been raised as to the possibility of the operator being hurt by the "Boyer" hammer or riveter, if the chisel or snap accidentally slipped off the work, it should be observed that the tool could not be operated unless it was actually being pressed against the work by the operator, so that if for any reason the tool should slip the air-supply was automatically cut off, and no damage could be done to the operator or the work. This

(Mr. William Reavell.)

riveter had been successfully used in driving ⅞-inch rivets through ¾-inch plates. He had himself closed ⅞-inch rivets in 15 seconds each; and although this speed had not been attained in regular working, he was informed that three rivets of this size could be easily driven per minute. He quite agreed with Mr. Simpson (page 156) as to the great convenience of compressed air, and had found that there were numerous other uses to which a pneumatic plant could be put. For example, in their own works, compressed air was used for keeping the shop-motors clean internally; and in the pattern shops especially it was found extremely useful, not only for this purpose, but also for cleaning down the machines. In connection with the water-supply, which was obtained from their own well, the pump, which was arranged to deliver water from a well to an elevated tank which supplies the building, was controlled automatically from this tank, and worked entirely by means of compressed air instead of steam; and as the pump, in many cases, was working extremely slowly, there was unquestionably a saving compared with steam, since all losses, due to the condensation of steam, were avoided.

Mr. T. HURRY RICHES, Vice-President, in addition to his remarks (page 153) in the discussion, forwarded the following information:—

Working results of Pneumatic Drilling Machines.

No. 1 Machine.

Drilling	½	inch hole	through	1¼	inch	mild	steel	plate,	3 mins. 15 secs.
,,	¾	,,	,,	1¼	,,	,,	,,	,,	4 mins.
,,	1	,,	,,	1¼	,,	,,	,,	,,	6 mins. 25 secs.
,,	1¼	,,	,,	1¼	,,	,,	,,	,,	8 mins. 10 secs.

No. 2 Machine.

Drilling	½	inch hole	through	1¼	inch	mild	steel	plate,	5 mins. 20 secs.
,,	¾	,,	,,	1¼	,,	,,	,,	,,	7 mins.
,,	1	,,	,,	1¼	,,	,,	,,	,,	11 mins. 30 secs.
,,	1¼	,,	,,	1¼	,,	,,	,,	,,	13 mins.

Pressure maintained in reservoir 60 lbs. Number of revolutions of compressor 140 average. The estimated contents of receiver and pipes about 34 cubic feet; and in testing the capabilities of the respective machines the results were as follows:—

No. 1 Machine. Compressor stopped. Pressure in receiver at 60 lbs., and after working 3½ minutes pressure fell to 30 lbs., after 5½ minutes to 21 lbs. and machine stopped.

No. 2 Machine. Compressor stopped. Pressure in receiver at 60 lbs., and after working 4¼ minutes pressure fell to 30 lbs., after 5 minutes to 20 lbs. and machine stopped.

The average result of the caulking by a machine was about 2 feet 9 inches per minute. Pressure average 50 lbs. per square inch in reservoir.

The Manufacturers of the "Monarch" Pneumatic Chipping and Caulking Hammer and the "Bradford" portable power Drill and Reamer wrote that the hammer shown in Fig. 48, Plate 25, was invented with the idea of securing the most effective blow with the least possible recoil. The amount of air actuating the piston on the return stroke was less than that which propelled it forward. A recess in the cap formed a cushion for the hammer. At present only two sizes were being made; one of them weighing 10¾ lbs. had an 18 oz. piston with 3 inches stroke, and 15 cubic feet of free air at 80 lbs. pressure were consumed per minute; the other weighing 9¼ lbs. had a 14 oz. piston with stroke of 2 inches, the air-consumption per minute being 14 cubic feet. The chief novel feature about this hammer was the arrangement of the handle, which formed a reservoir for the regular lubrication of the internal parts, and helped to reduce the hand vibration. Fig. 52, Plate 27, showed the "Bradford" power drill and reamer. The motor was of the rotary type, and the piston was placed eccentrically in the cylinder. Blades slid to and fro through a slot in the piston, and always maintained contact with the opposite walls of the cylinder, in whatever position the piston might be. The air-consumption was somewhat greater than in the case of piston-driven drills, being approximately 45 cubic feet of air per minute. The work done was in proportion to the amount of air consumed, which was an advantage where speed was a necessary factor. In addition, the arrangements were such that it worked equally well with steam, and a reversing valve might be provided which enabled the machine to be reversed when running full speed without injury to any of the parts. For tapping purposes this was a great advantage. When this drill was first made, ball-bearings were used to take the thrust at the point of contact between the stationary cylinder and the rotating bowl. In practice however, this ball-bearing was found to be inefficient, owing to the pressure which was constantly exerted upon it. It was now superseded by a phosphor bronze and white metal cone-bearing, which gave perfect satisfaction, and was more reliable in regular work than the earlier arrangement.

Mr. AMOS wrote that, a desire having been expressed in the course of the discussion for further data as to the actual results obtained from the "Little Giant" tools, he had since obtained from works at Chippenham, Swindon, and Wolverton the results given on page 179.

With regard to Mr. Atkinson's remark (page 172), that his hammer was the pioneer of the pneumatic tool, it would seem that a similar claim was made by other inventors.

The rate of speed claimed by Messrs. Beyer, Peacock and Co. was not necessarily an advantage, since it was now well recognised that whilst the valveless hammers ran faster than those which were fitted with an automatic distributing valve, yet they had been to a very large extent superseded by the valve hammer, and so far as speed was concerned both the "Atkinson" and "Ross" hammers ran at very high speeds.

Mr. Riches (page 176) gave some data as to the work done by pneumatic drilling machines. The time taken in these instances was considerably longer than some of the latest types of machines now required, and it was somewhat unusual for a $\frac{1}{2}$-inch hole to require half the time taken to drill a 1-inch hole. This relation of time appeared to occur with both machines, which pointed to the probability of the machine having been used beyond its capacity. In the author's

TABLE 5.—*Tests made with "Little Giant" Pneumatic Tools, April*, 1900.

Type of Machine.	Work done.	Time taken.		Average pressure of air used per sq. inch.
		Mins.	Secs.	Lbs.
2,000 lbs. Pneumatic Chain Hoist .	1,980 lbs. weight lifted 6 feet high.	1	0	72
No. 2 Drill . .	Drilling 1-inch diameter holes through toughened steel armour-plate 4¼ inches thick.	9	15	70
No. 2 Drill, fitted with circular band-saw . .	Cutting out in one piece a disc of wood 7 inches diameter by 1-inch thick for lamp-hole in railway carriage.	0	30	100
No. 12 Reversible Drill . . .	Expanding locomotive boiler-tubes, 1⅞ inches outside diameter.	0	30	70
No. 5 Reversible Drill . . .	Expanding 1-inch diameter steel condenser-tubes.	0	30	70
No. 2 Hammer .	Riveting 1-inch diameter copper stays, knocking down and finishing with snap.	2	30	71
No. 2 Hammer .	Riveting 1-inch diameter wrought-iron studs cold.	1	0	70
No. 2 Hammer .	Chipping Bessemer steel-plates ½-inch wide, the chipping taken off being ½-inch thick by 18 inches long, and weighing 11 lbs. 10 ozs. in one piece.	2	56	71

NOTE.—The boiler-tube test was made at the Great Western Railway Works at Swindon, and the cutting lamp-holes at the London & North Western Railway Works at Wolverton.

opinion, it was very desirable that the useful capacity of any machine should be carefully determined and not exceeded, and, as in other classes of machines, it was better to use two or more machines of different sizes than apply one for doing work beyond its range.

The deep interest evinced by the members in his Paper had been very gratifying to the author, and he hoped on some future occasion to place before the Institution further data in reference to a class of machine that was likely to produce immense advantages and changes in the engineering industry.

WATER METERS. *Plate I.*

"Imperial"

½-inch Positive Meter. (Schönheyder.)

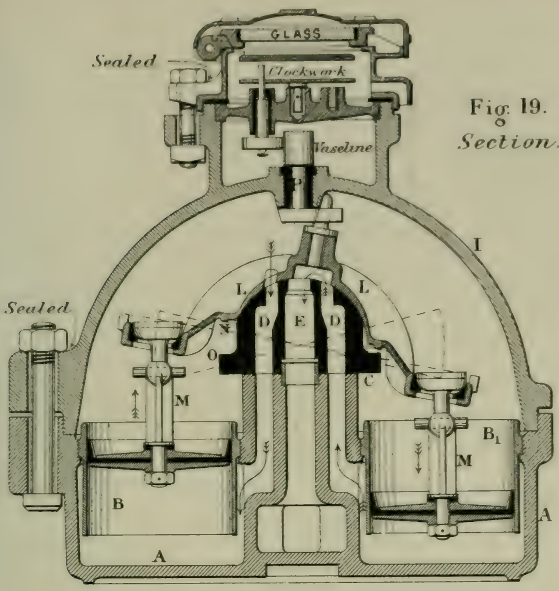
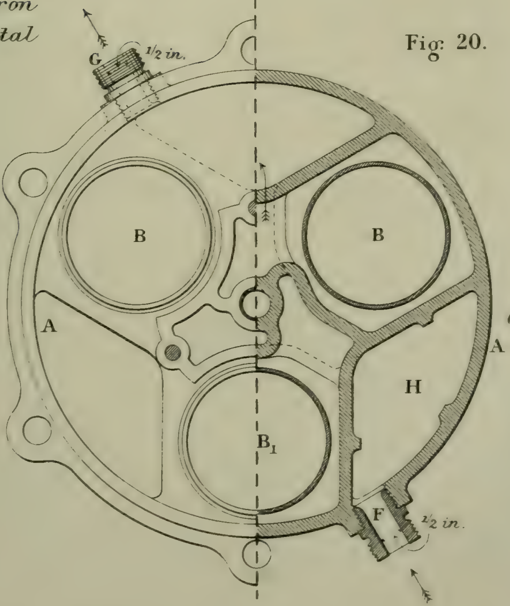


Fig. 19.
Section.

▨ *Cast-iron*
▩ *Gunmetal*

Fig. 20.

Plan. Valve and Seating removed



Section through Cylinders.

¼ Full size.

WATER METERS. *Plate 2.*

"Imperial"

½-inch Positive Meter. (Schönheyder.)

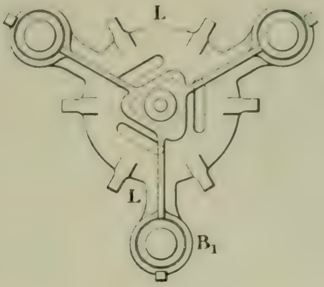


Fig. 21.
Valve.

▨ *Cast-iron*

■ *Gunmetal*

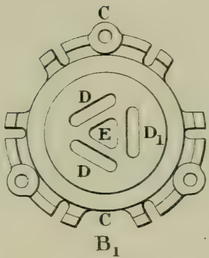


Fig. 22.
Vulcanite Seating.

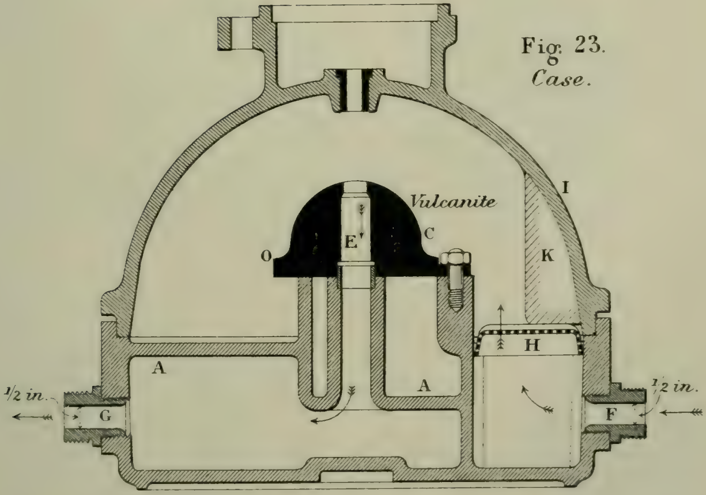


Fig. 23.
Case.

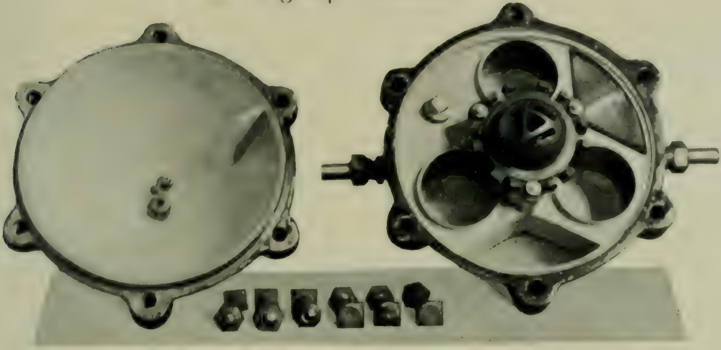
Mechanical Engineers 1900.

¼ Full size.

WATER METERS.

"Imperial" ½-inch Positive Meter. (Schönheyder).

Fig. 24. *Unused.*



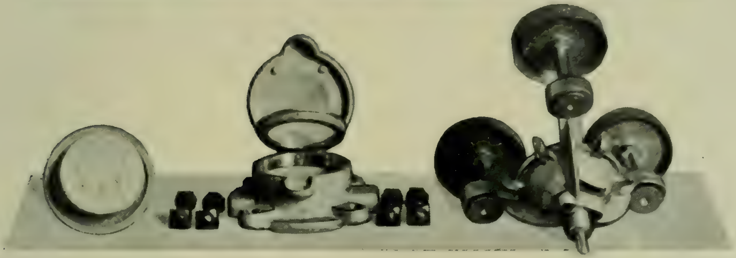


Fig. 25.

After 2 years 5 months use.

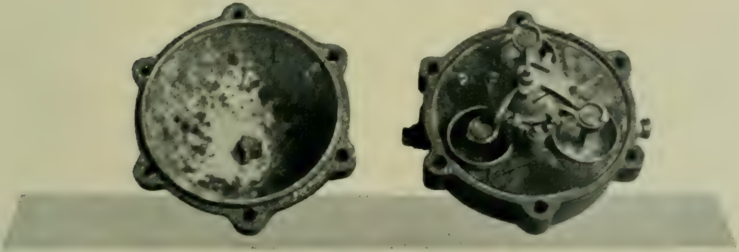


Fig. 26. *"Lacoste Domestic."*

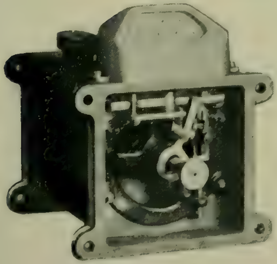
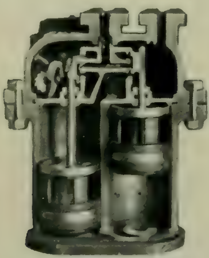


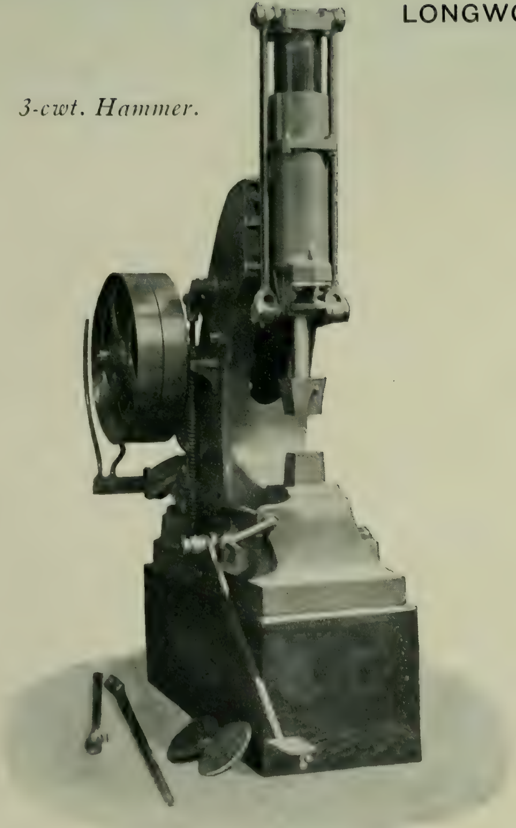
Fig. 27. *"Frager."*



Mechanical Engineers 1900.

LONGWORTH POWER-HAMMER.

3-cwt. Hammer.



Roller Chain
Riveted by Hammer.

1-lb. Riveting Hammer.

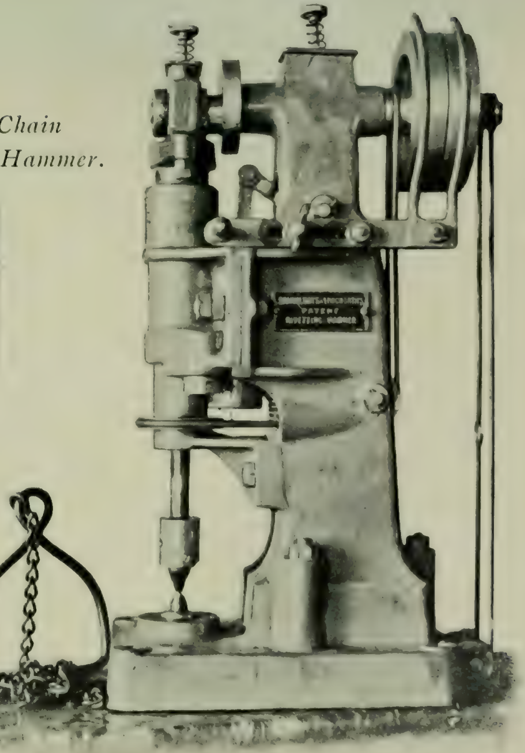
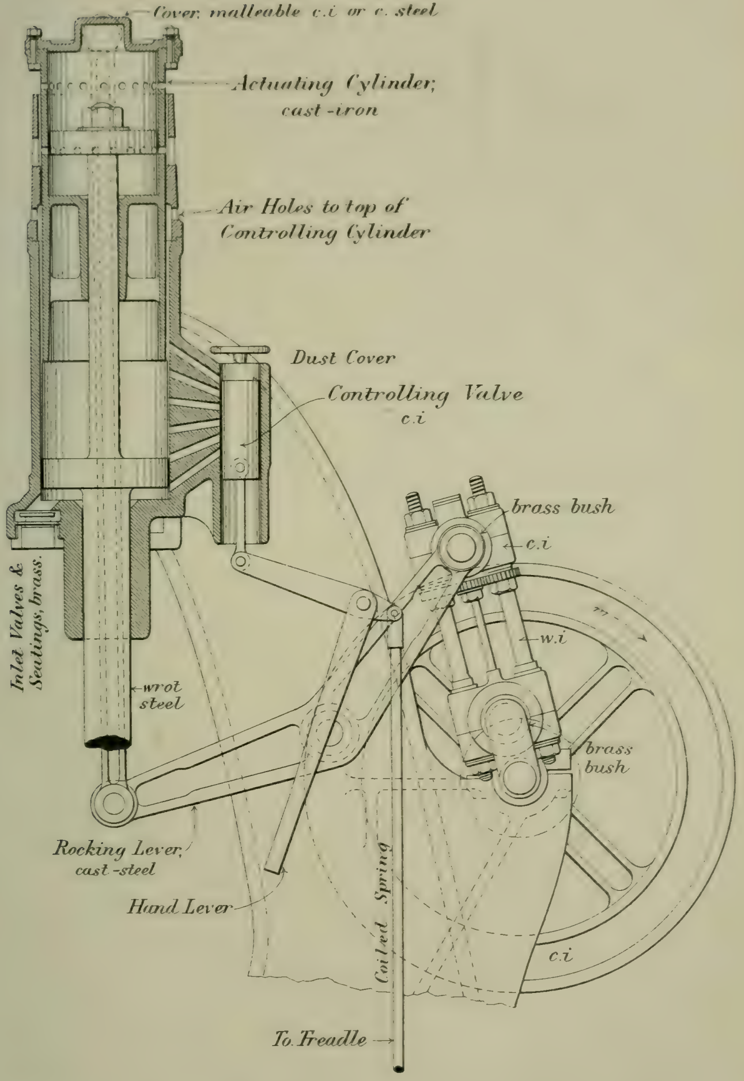


Plate 4.

LONGWORTH POWER-HAMMER. *Plate 5.*

Gearing for 3-cwt. Hammer.

Fig. 2. *Section.*


Cover, malleable c.i. or c. steel
Actuating Cylinder; cast-iron
Air Holes to top of Controlling Cylinder
Dust Cover
Controlling Valve c.i
brass bush
c.i
w.i
brass bush
Inlet Valves & Seatings, brass.
wrot steel
Rocking Lever, cast-steel
Hand Lever
Coiled Spring
c.i
To Treadle

LONGWORTH POWER-HAMMER. *Plate 6.*

3-cwt, Single Standard, Self-contained Hammer.

Fig: 3.

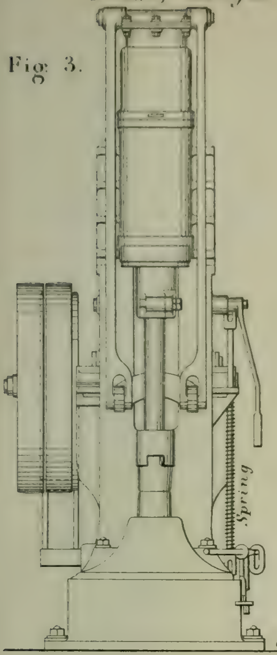


Fig: 4.

Suitable for General Forging.

Scale 1/32nd.

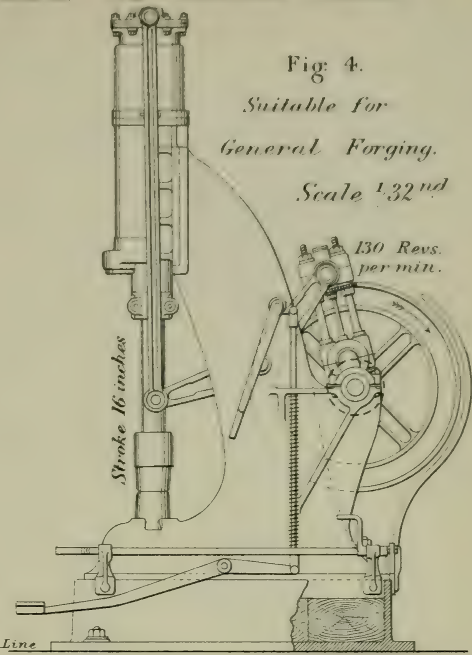
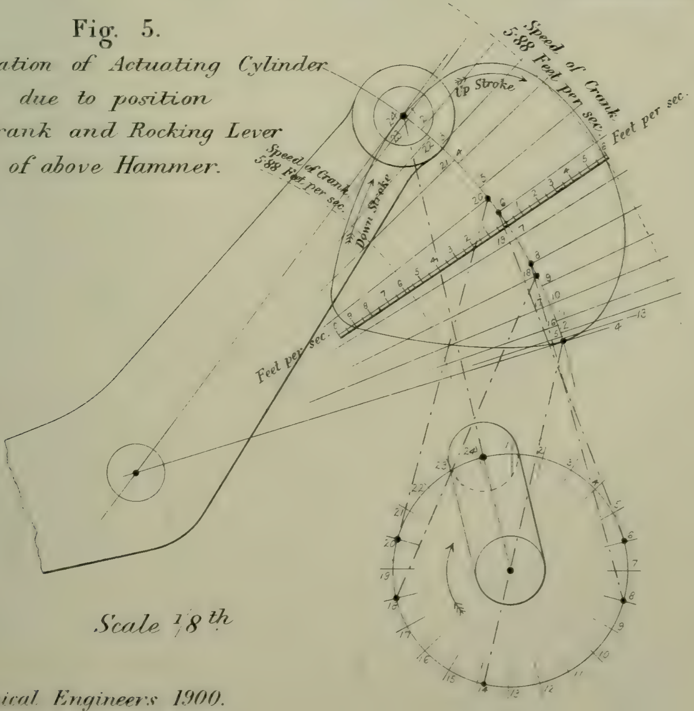


Fig. 5.

Acceleration of Actuating Cylinder due to position of Crank and Rocking Lever of above Hammer.


Speed of Crank 5·88 Feet per sec.
Up Stroke
Feet per sec.
Speed of Crank 5·88 Feet per sec.
Down Stroke
Feet per sec.

Scale 1/8th.

LONGWORTH POWER-HAMMER. *Plate 7.*

1-lb. Riveting Hammer.

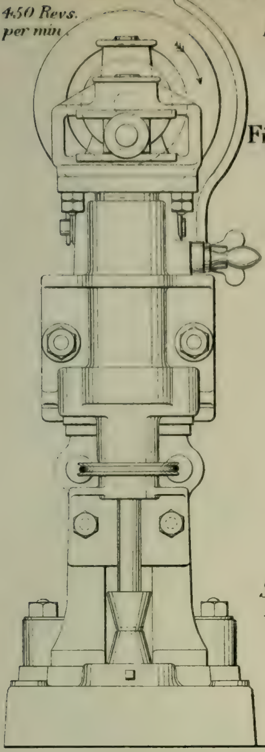
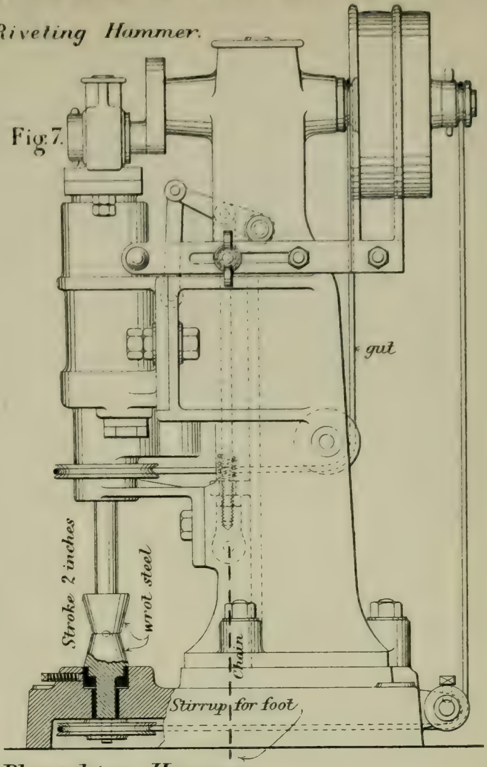


Fig. 6.

Fig. 7.



Scale 1/6th.

20-lbs. Planishing Hammer.

Fig. 8.

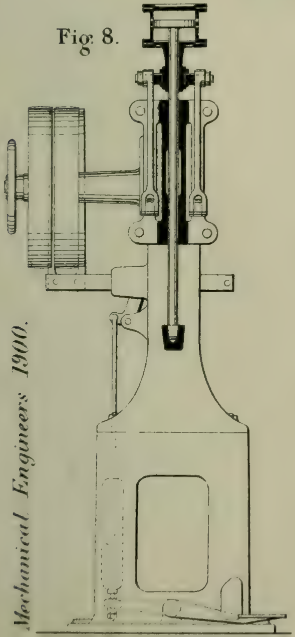
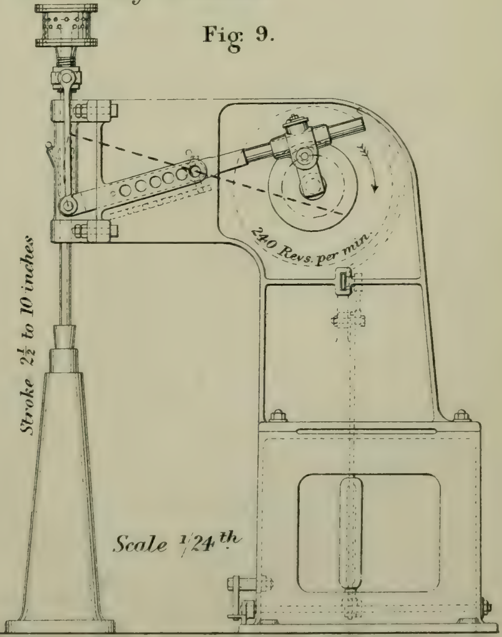


Fig. 9.

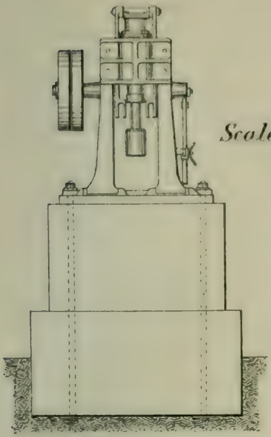


Scale 1/24th.

LONGWORTH POWER-HAMMER

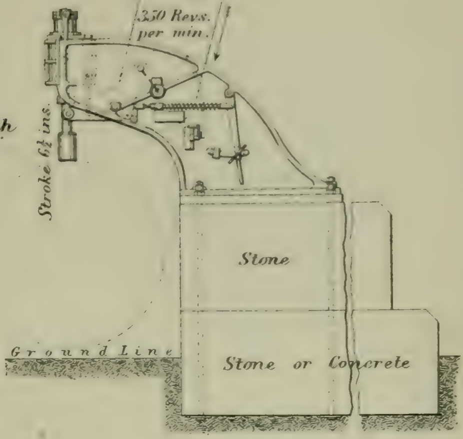
1-cwt. Hammer for Tube Welding.

Fig: 10.



Scale 1/48th

Fig: 11.



Hammers for Stamping and General Forging.

Fig 12. *3-cwt.*

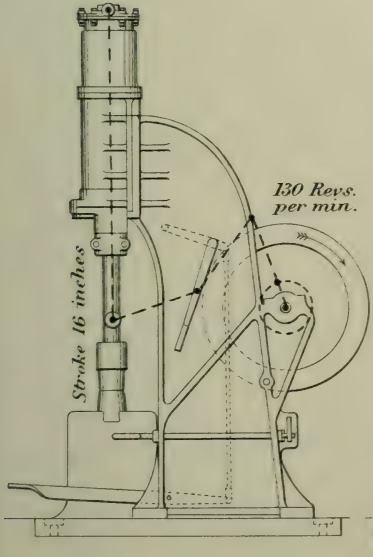
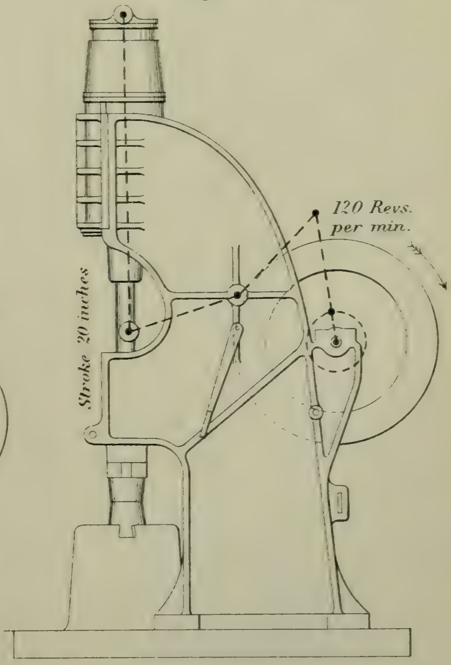
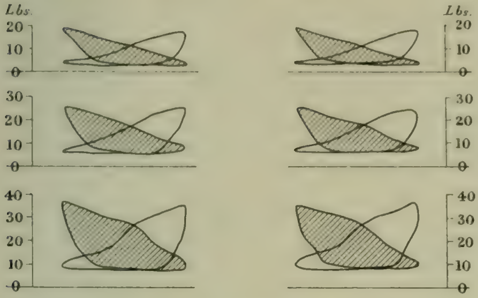


Fig 13. *7-cwt.*



Scale 1/40th

Fig: 14. *Diagrams of Steam-Engine. Cyl. 11" diam. 10" stroke. 205 revs. Driving 3-cwt. Hammer.*



Engine and Countershaft only
6·3 I.H.P.

Hammer Light
9·4 I.H.P.
Actual Power required 3·1 I.H.P.

Hammer Full Blow 16" Stroke
15 I.H.P.
Actual Power required 8·7 I.H.P.

Fig: 15. *Diagrams of 3-cwt. Hammer. 132 blows per min. 368 lbs. falling weight. Driven by above Engine.*

Actuating Cylinder $9\frac{1}{4}$" diam. *Controlling Cylinder*
Top of Piston. *Bottom of Piston.* *11 inches diam.*

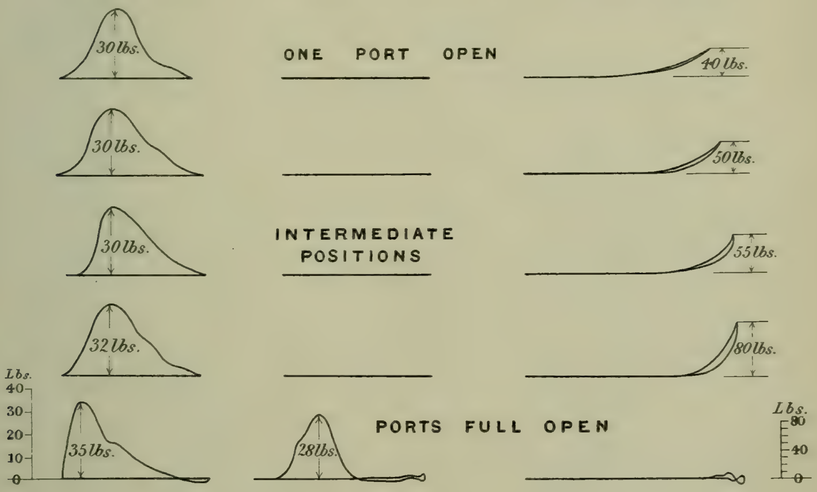
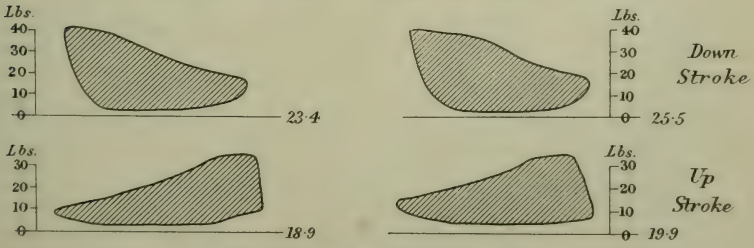


Fig: 16. *Diagrams of 4-cwt.* STEAM – *Hammer (420 lbs.)*
Cyl. 8" diam. 16" stroke. 120 blows per min. 10 I.H.P.



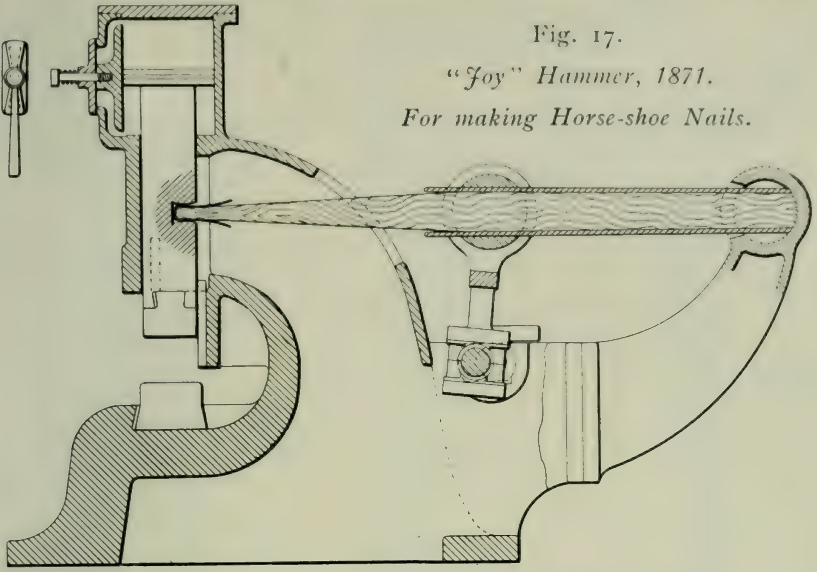
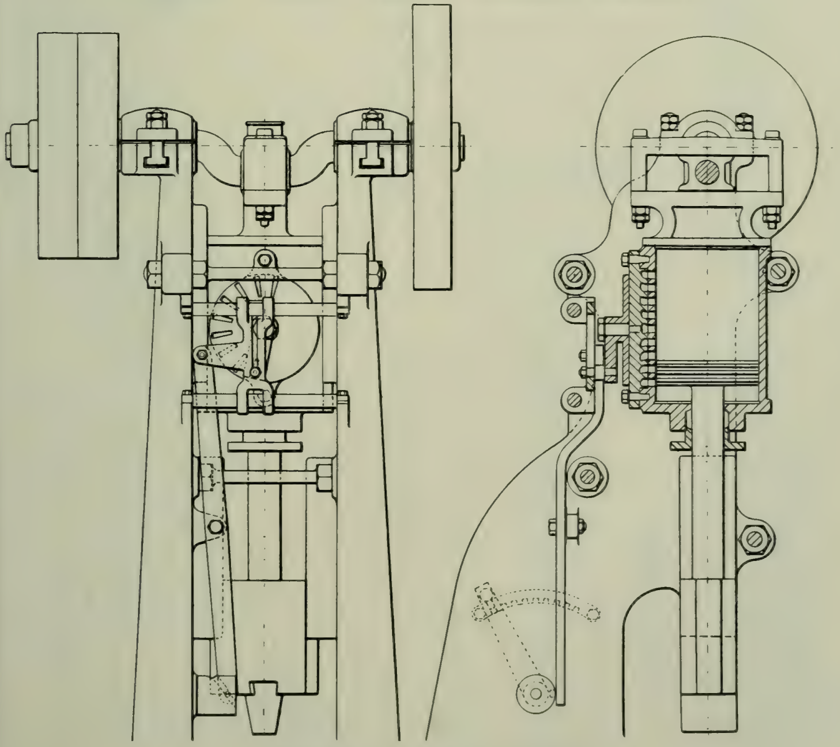


Fig. 17.

"Joy" Hammer, 1871.

For making Horse-shoe Nails.

Fig. 18. *3-cwt. "Player" Pneumatic Hammer.*



PORTABLE PNEUMATIC TOOLS.

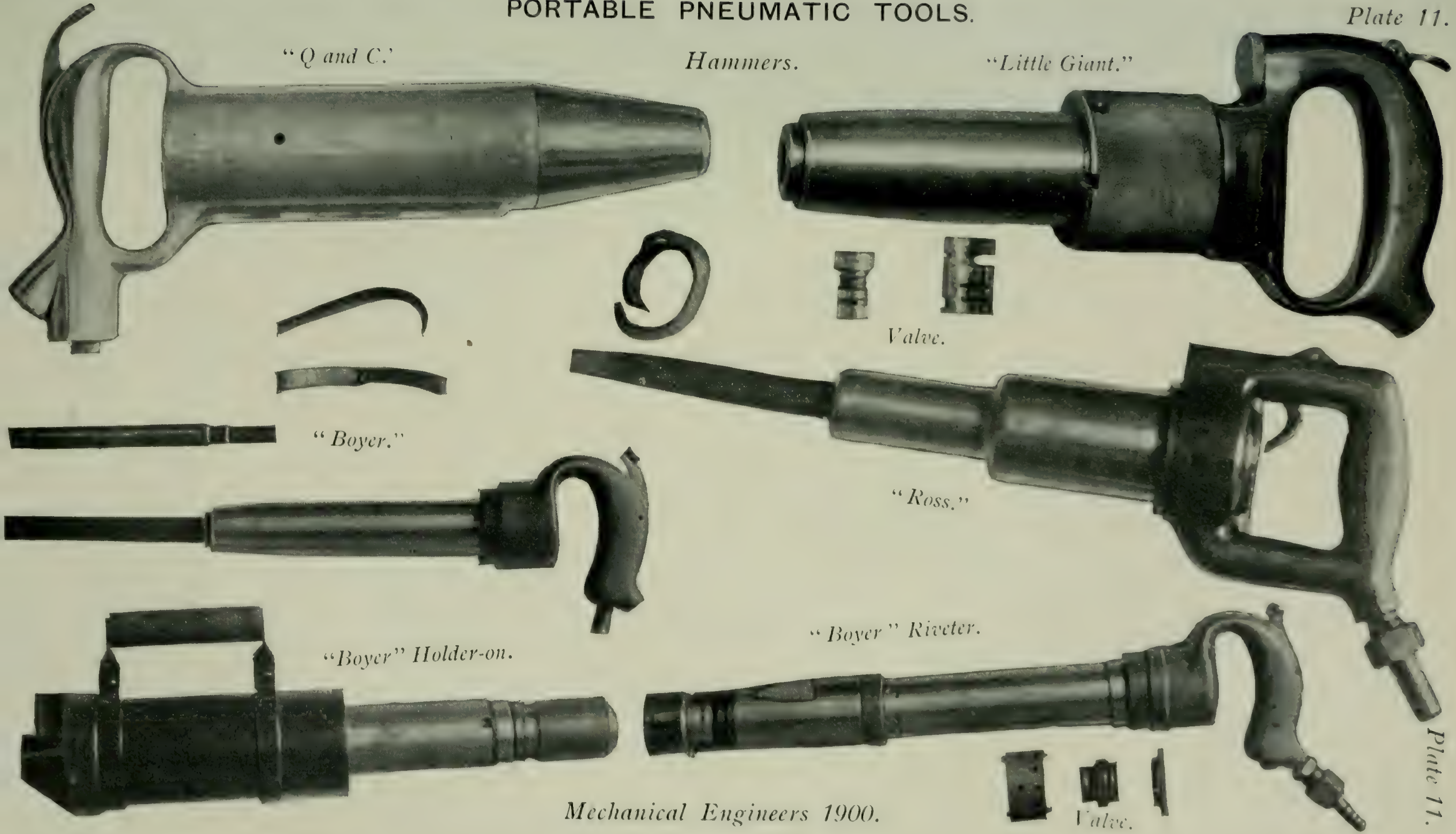


Fig. 1. *"Ross" Hammer.*

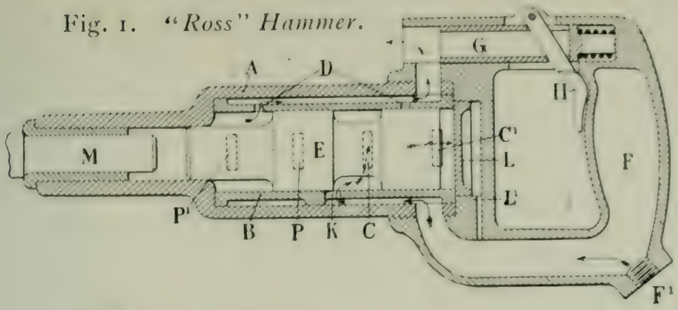
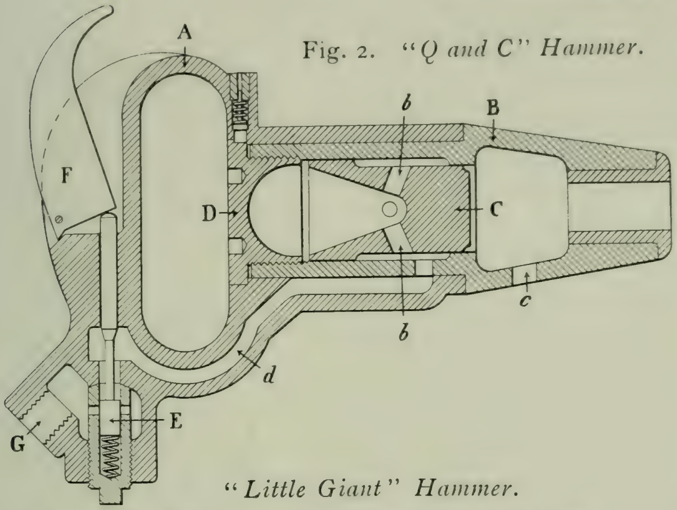


Fig. 2. *"Q and C" Hammer.*



"Little Giant" Hammer.

Fig. 3. *Left half.*

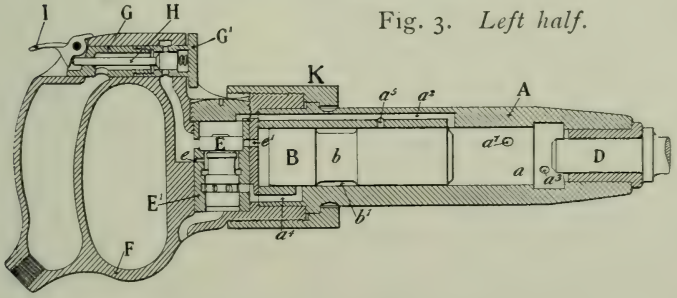
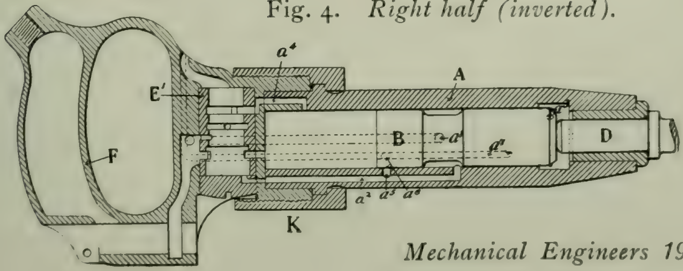


Fig. 4. *Right half (inverted).*



PORTABLE PNEUMATIC TOOLS. *Plate 13.*

"Little Giant" Hammer.

Piston and Valve in extreme positions.

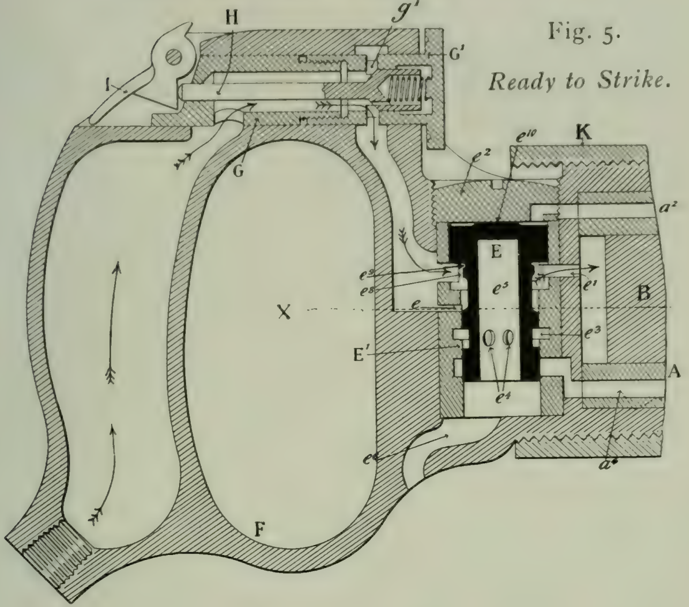


Fig. 5.

Ready to Strike.

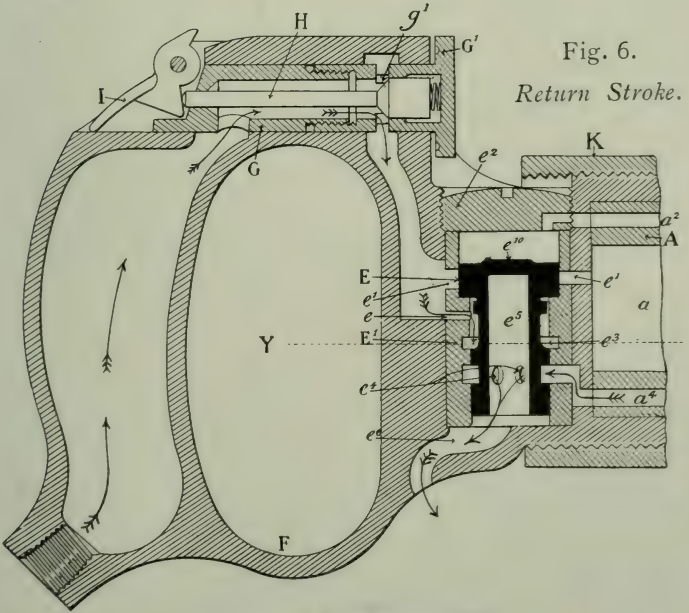


Fig. 6.

Return Stroke.

"Little Giant" Hammer.

Fig. 7. *Section at X, Fig. 5.*

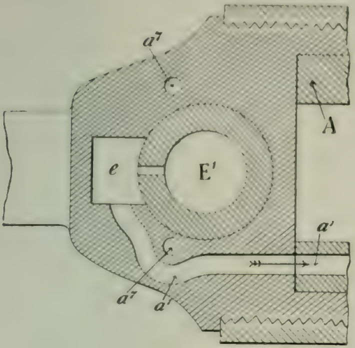
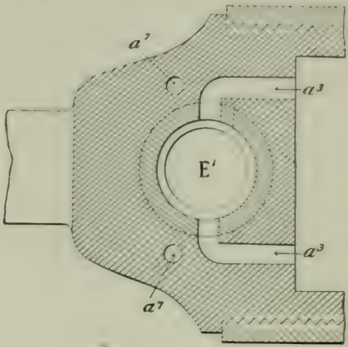


Fig. 8. *Section at Y, Fig. 6.*



"Boyer" Hammer. (See also Fig. 45.)

Fig. 9.

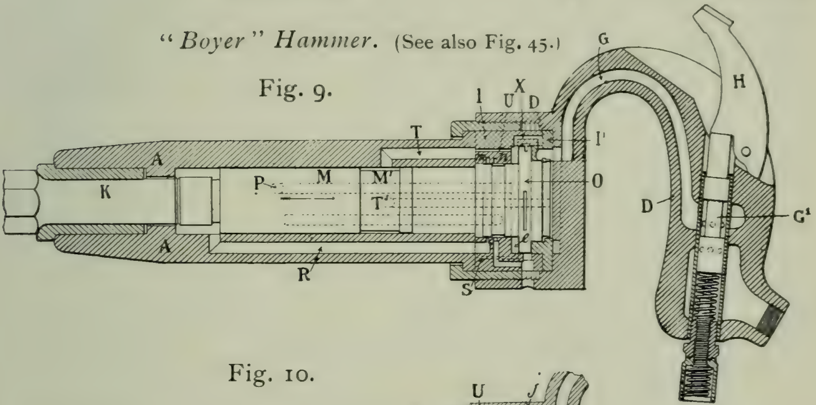


Fig. 10.

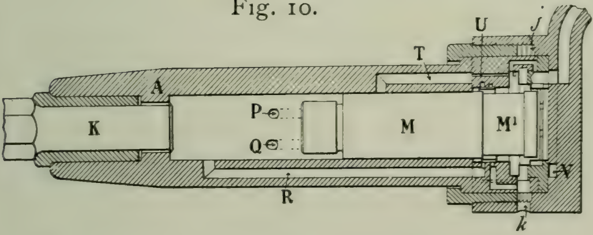


Fig. 11.

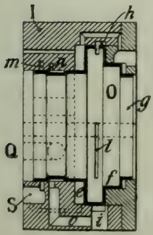


Fig. 12.

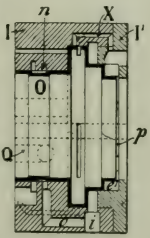


Fig. 13.

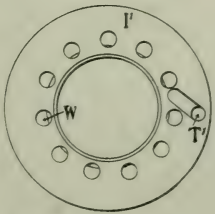
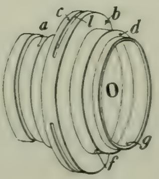


Fig. 14.



“Boyer” Pneumatic Riveter with Pipe Gap-Frame.

Fig. 15.

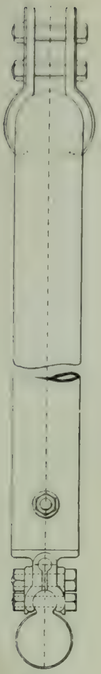


Fig. 16.

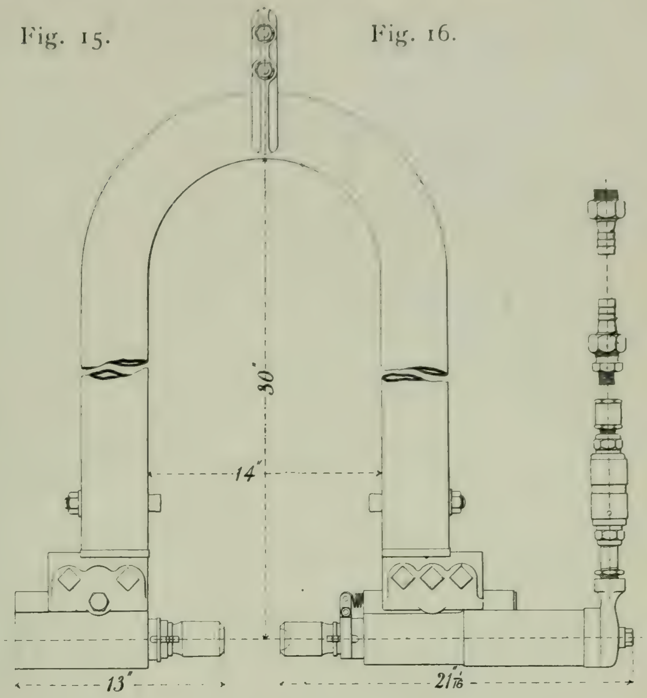
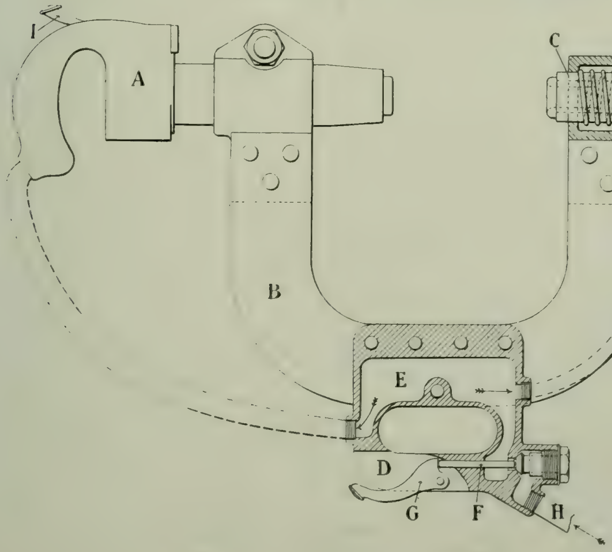


Fig. 17. *“Little Giant” Light Yoke Riveter.*



PORTABLE PNEUMATIC TOOLS.

"Little Giant" Plate Closing Riveter.

Fig. 18. *Ready position.*

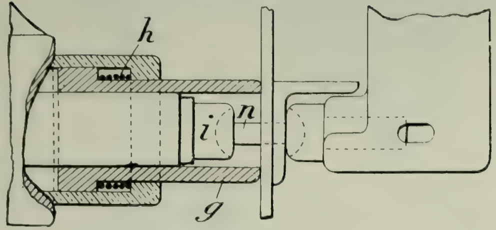


Fig. 19. *Section at AA.*

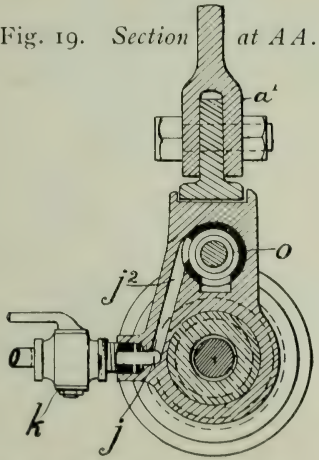
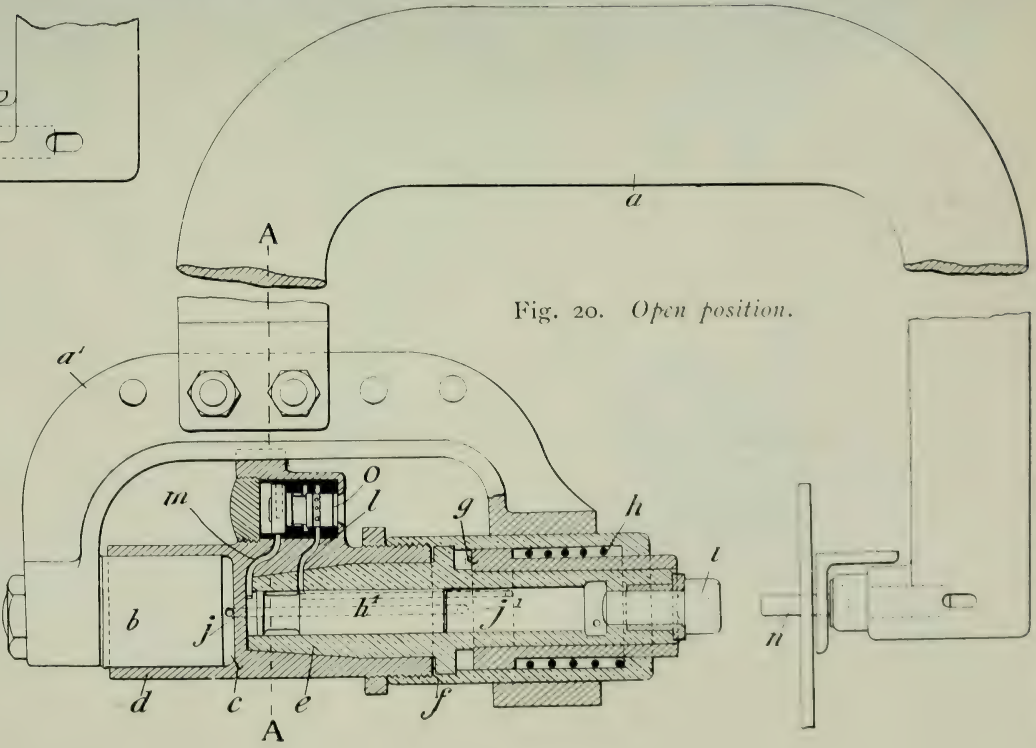


Fig. 20. *Open position.*

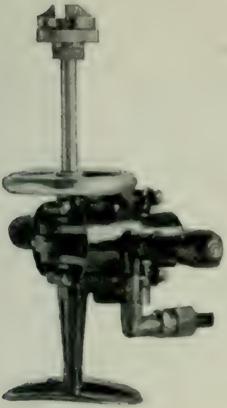


Mechanical Engineers 1900.

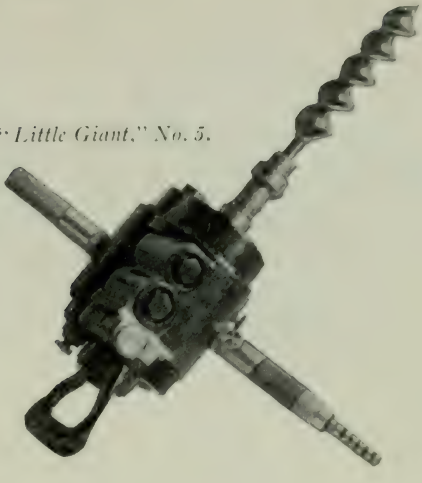
PORTABLE PNEUMATIC TOOLS. *Plate 17.*

Drills.

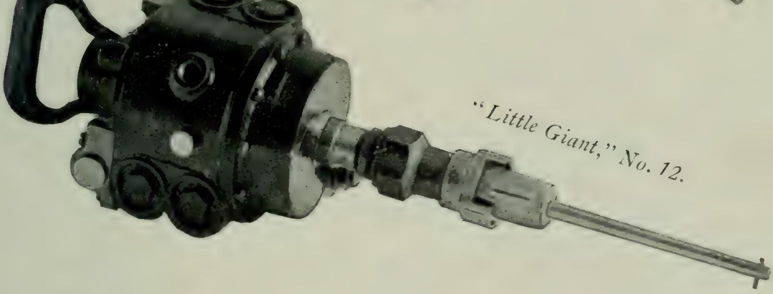
"Boyer"



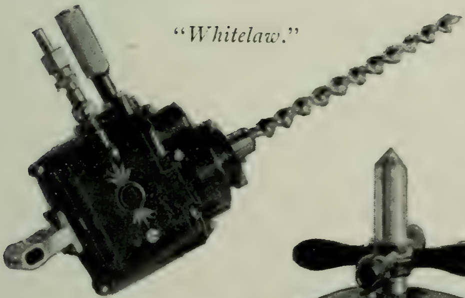
"Little Giant," No. 5.



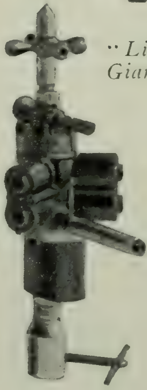
"Little Giant," No. 12.



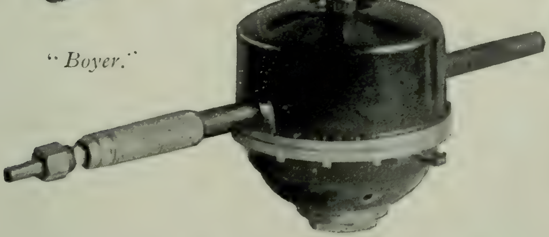
"Whitelaw."



"Little Giant."



"Boyer."



Mechanical Engineers 1900.

PORTABLE PNEUMATIC TOOLS.

"Little Giant" Portable Air-Drill.

Fig. 21.

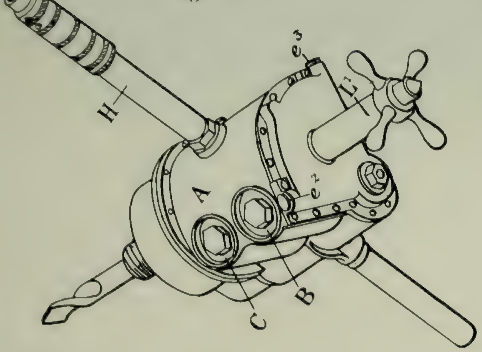
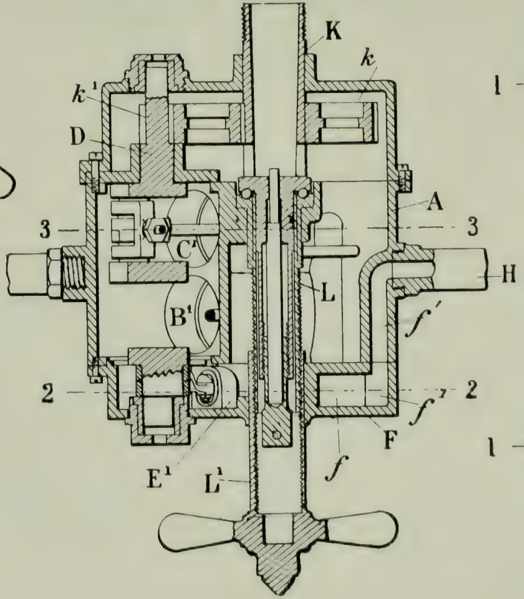


Fig. 22.

Longitudinal Section on 1-1.



Looking towards Drill.

Fig. 23.
Section
on 2-2.

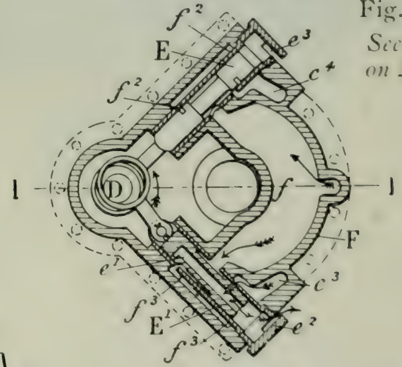


Fig. 24.
Section
on 3-3.

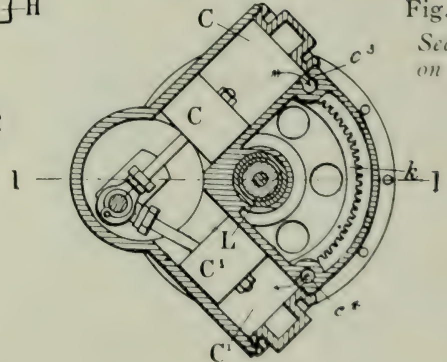
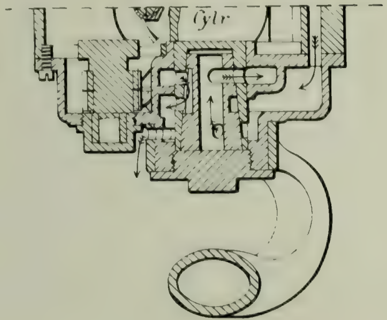


Fig. 25.

Reversing Arrangement.



PORTABLE PNEUMATIC TOOLS.

"Whitelaw" Drill.

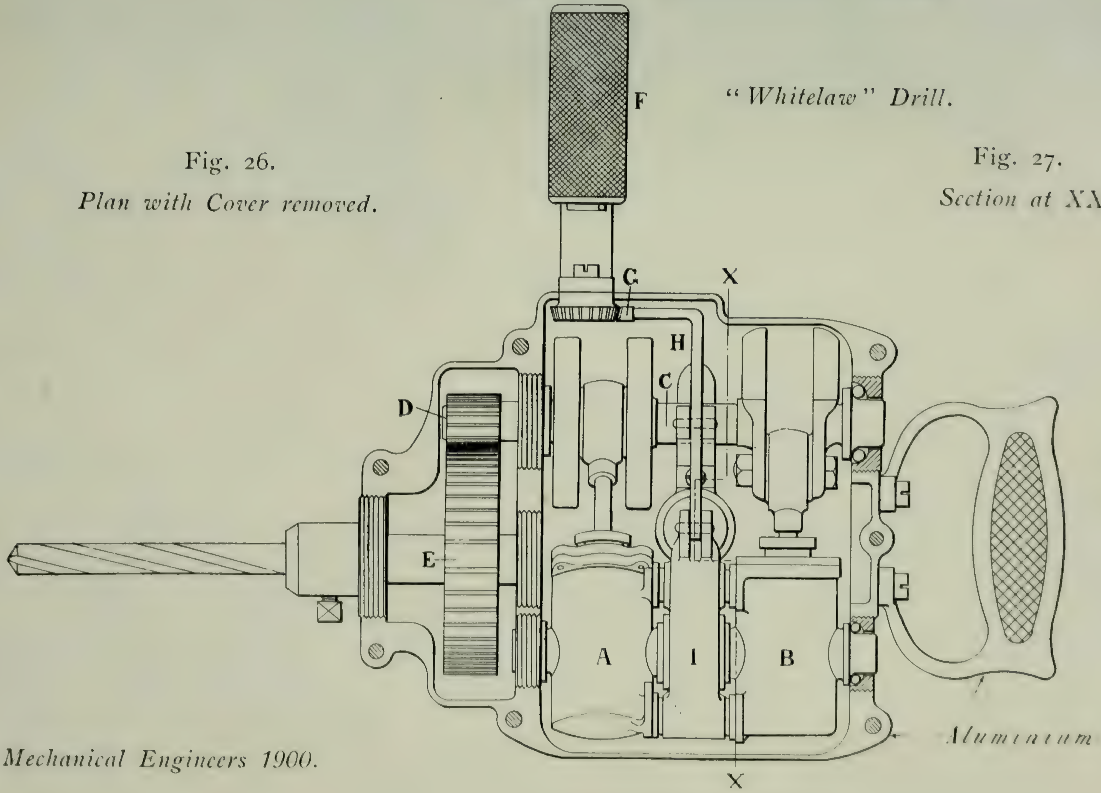


Fig. 26.

Plan with Cover removed.

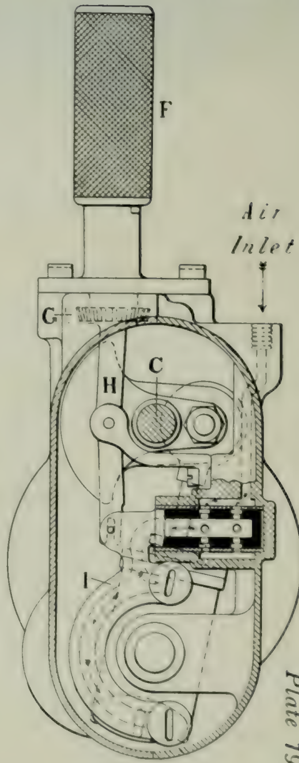


Fig. 27.

Section at XX.

Mechanical Engineers 1900.

"Boyer"
Piston Air Drill.

Fig. 28. *Vertical Section through centre of Machine. Scale $\frac{1}{3}$rd.*

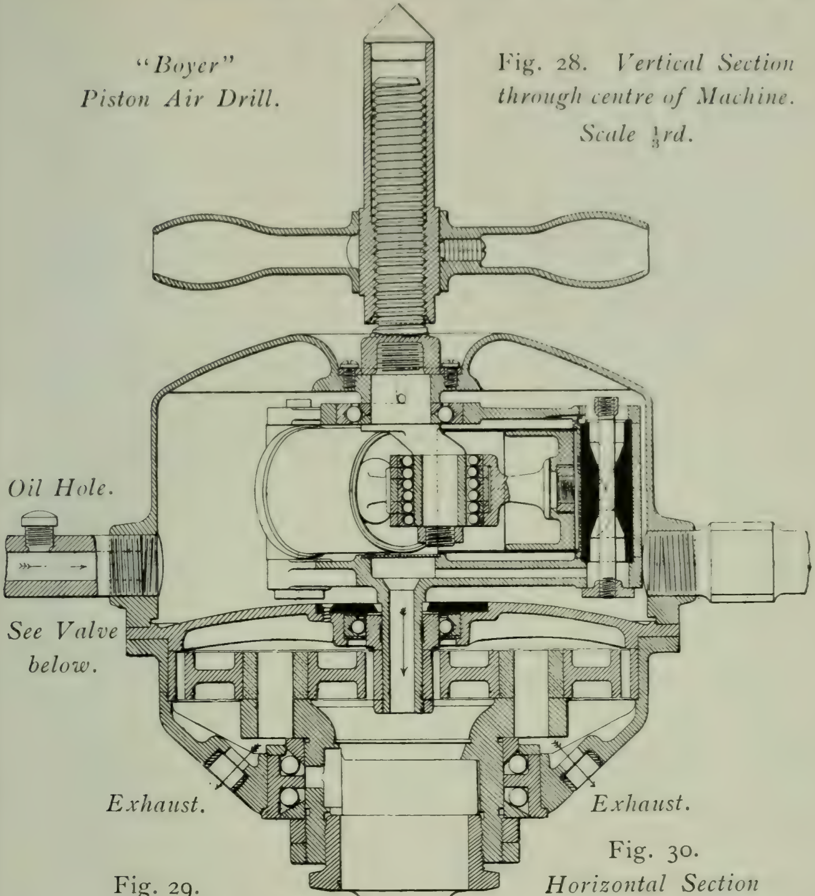


Fig. 29.

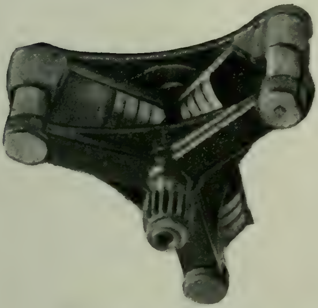
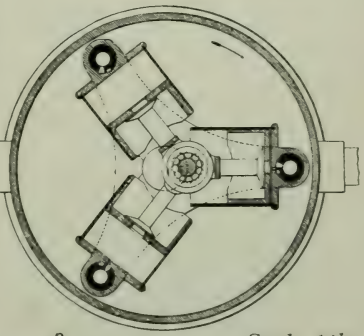
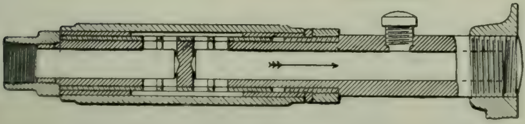


Fig. 30.
Horizontal Section through centre of Cylinders.



Scale $\frac{1}{5}$th.

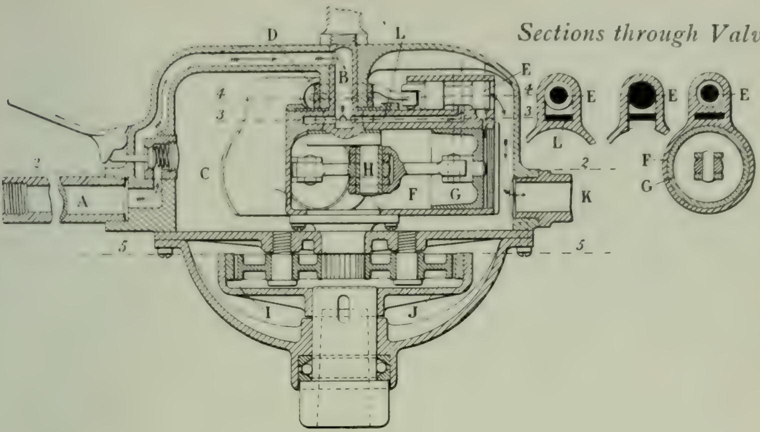
Regulating Valve, see above.



Mechanical Engineers 1900.

"Little Giant" High Speed Rotary Drill.

Fig. 31.



Sections through Valve.

Fig. 32. *Section on 2-2.*

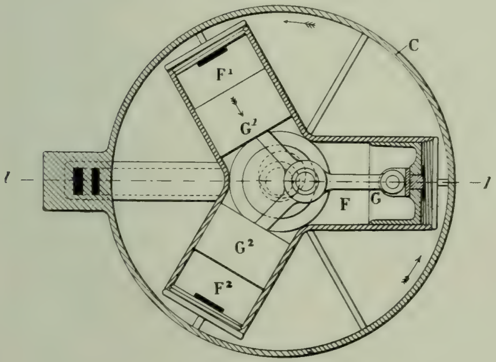


Fig. 33. *Section on 3-3.*

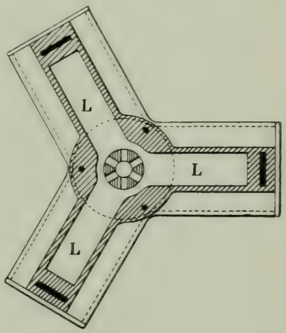


Fig. 34. *Section on 4-4.*

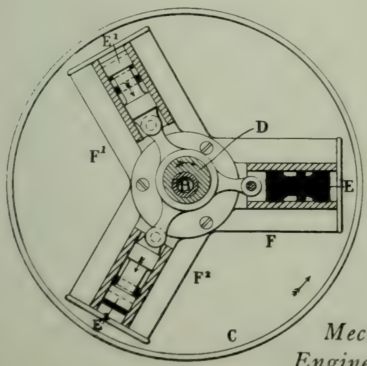


Fig. 35. *Section on 5-5.*

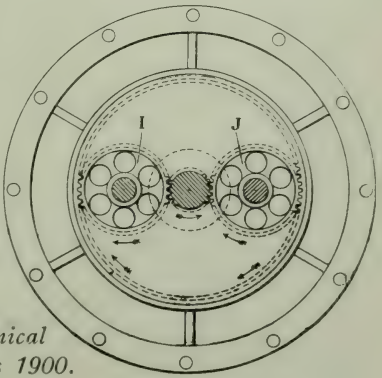
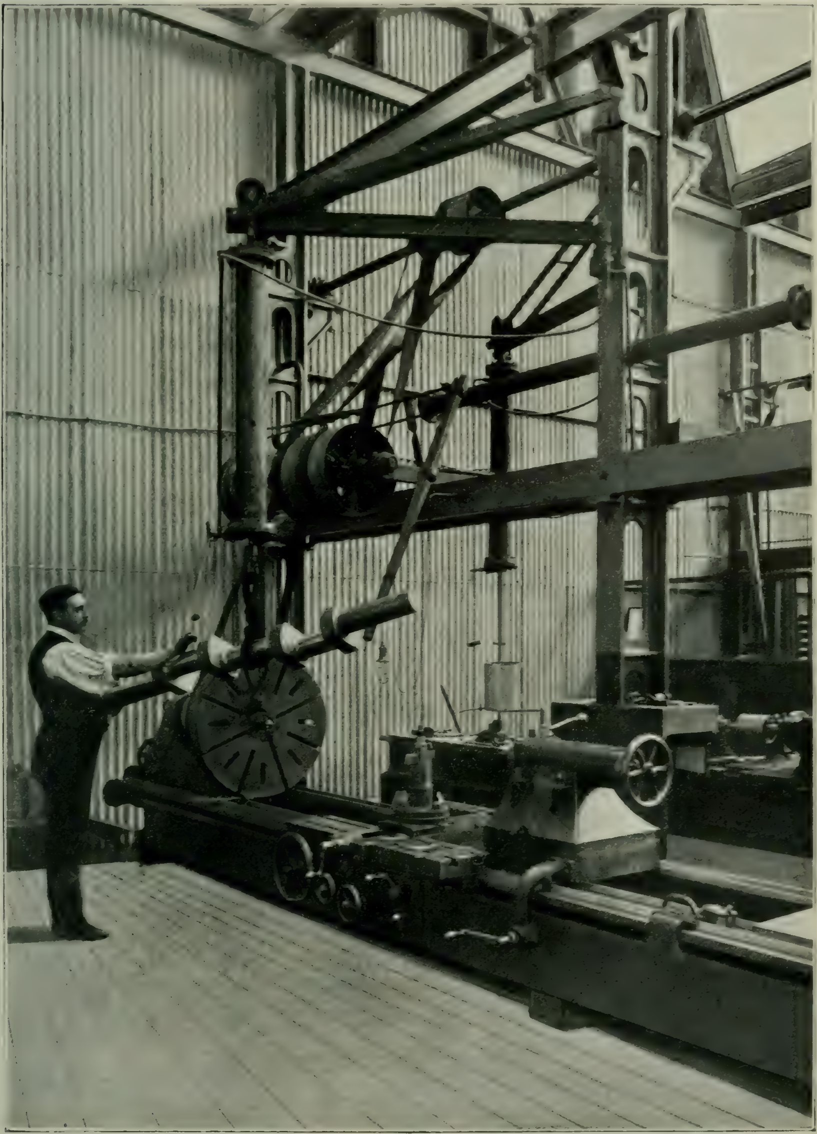


Fig. 36.

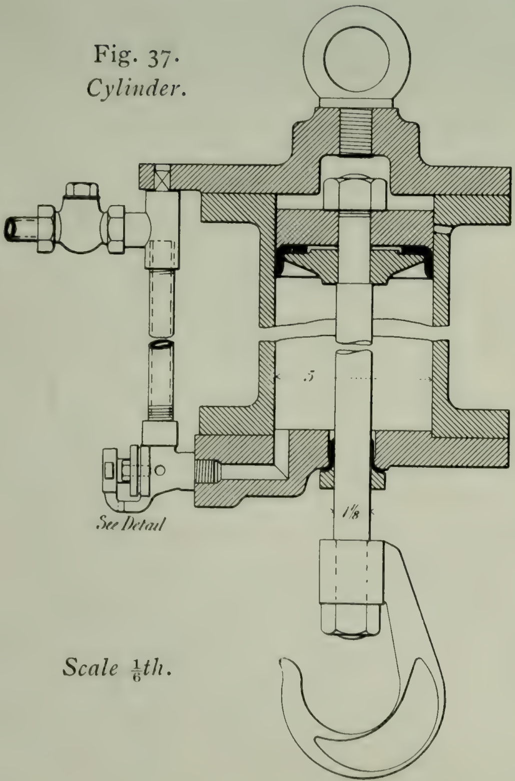
Air-Hoist upon light Jib, over a Lathe.



PORTABLE PNEUMATIC TOOLS.

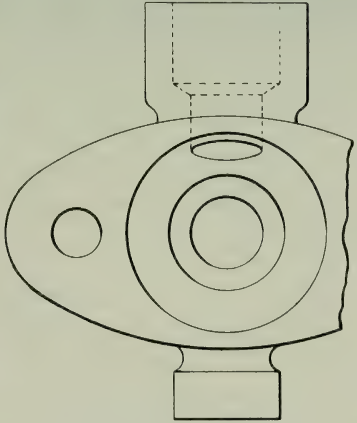
5-inch Air-Hoist.

Fig. 37.
Cylinder.



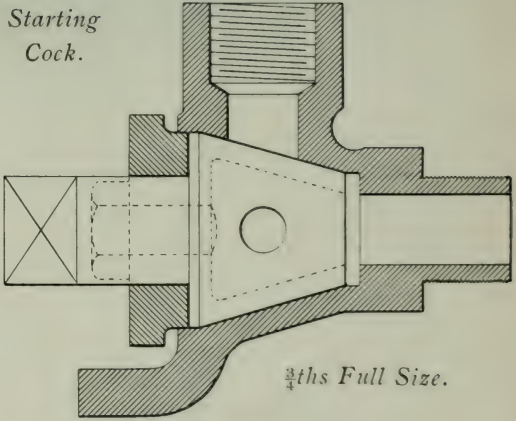
Scale $\frac{1}{6}$th.

Fig. 38.



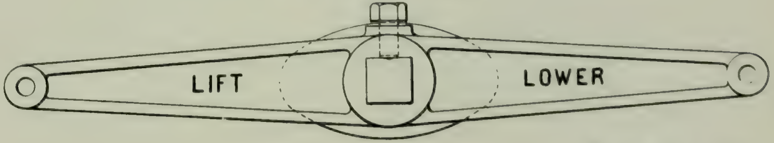
Starting Cock.

Fig. 39.



$\frac{3}{4}$ths Full Size.

Fig. 40. *Lever.*



$\frac{3}{8}$ths Full Size.

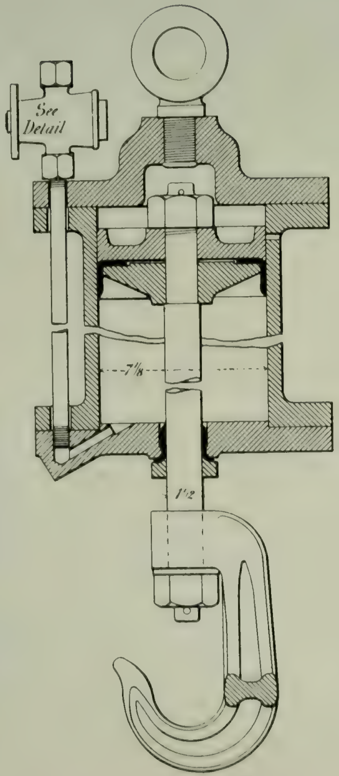
Mechanical Engineers 1900.

PORTABLE PNEUMATIC TOOLS.

7⅛-inch Air-Hoist.

Fig. 41.

Cylinder.



Scale ⅛th.

Safety Regulating Valve.

Fig. 42.

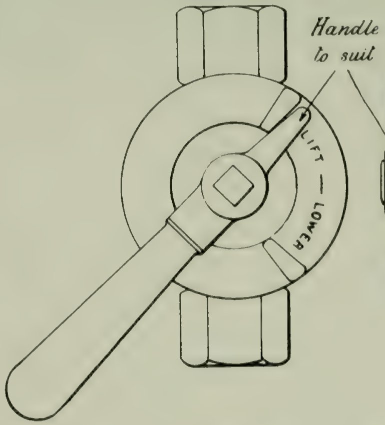


Fig. 43.

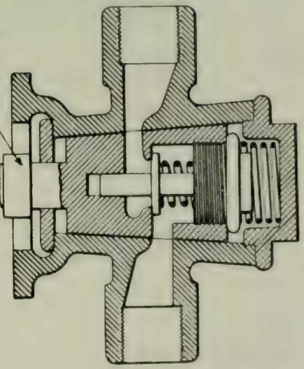
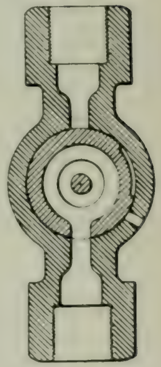


Fig. 44.



⅜ths Full size.

This Valve is in the form of a plug cock, the plug being fitted with a check valve, so arranged that in the event of failure to the hose pipe it is impossible for the air to be suddenly released, which might cause serious injury. The release is effected by a bye-pass in the side which allows the weight at all times to be lowered gently.

Both Hoists and Jacks are fitted with this Valve.

Mechanical Engineers 1900.

Fig. 45.

"Boyer" Long-Stroke Riveting-Hammer.

9 inches stroke.

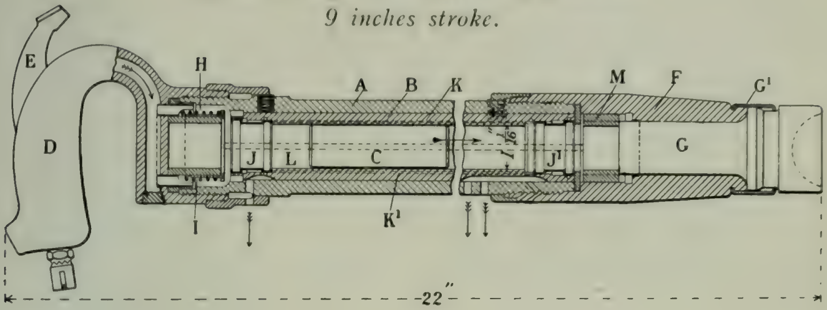


Fig. 46. *"Atkinson" (Crossley) Tool.*

Superseded by Fig. 50.

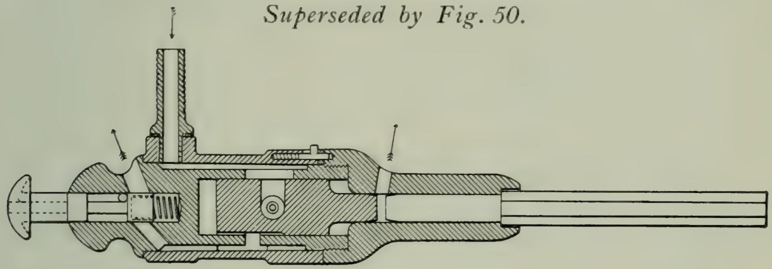


Fig. 47.

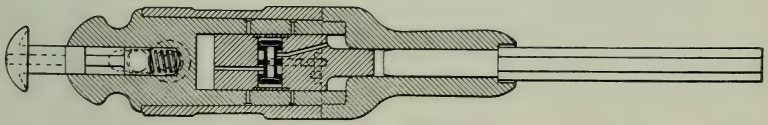
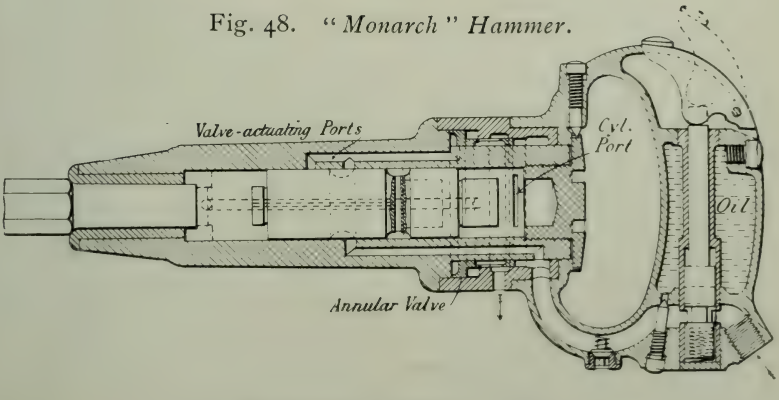


Fig. 48. *"Monarch" Hammer.*



Valveless Hammers.

Fig. 49. *"Fielden" Hammer, 1876.*

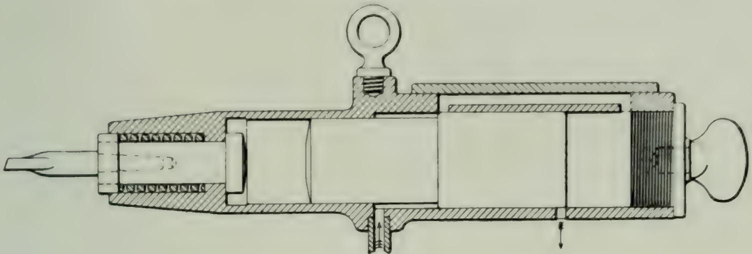


Fig. 50. *"Atkinson" (Crossley) Tool.*

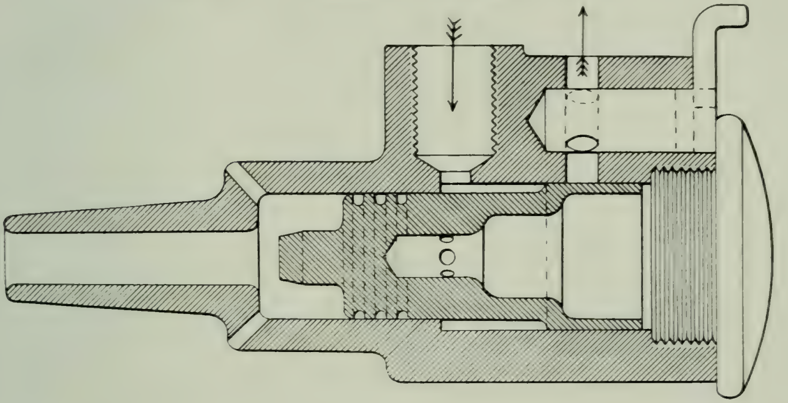


Fig. 51. *"Dunlop" Hammer, 1895.*

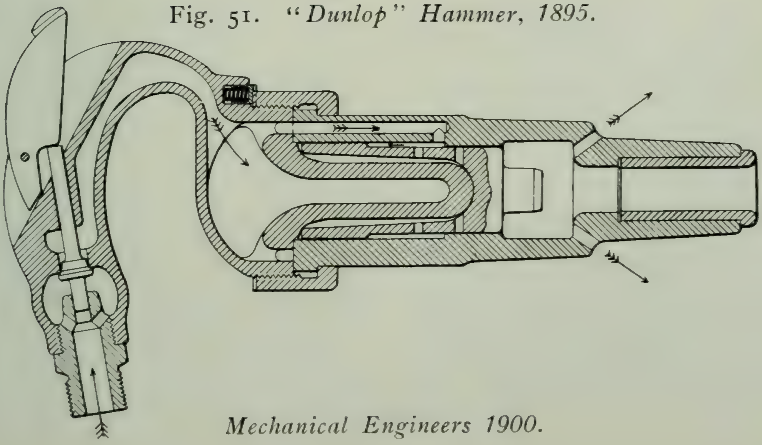


Fig. 52. *"Bradford" Drill.*

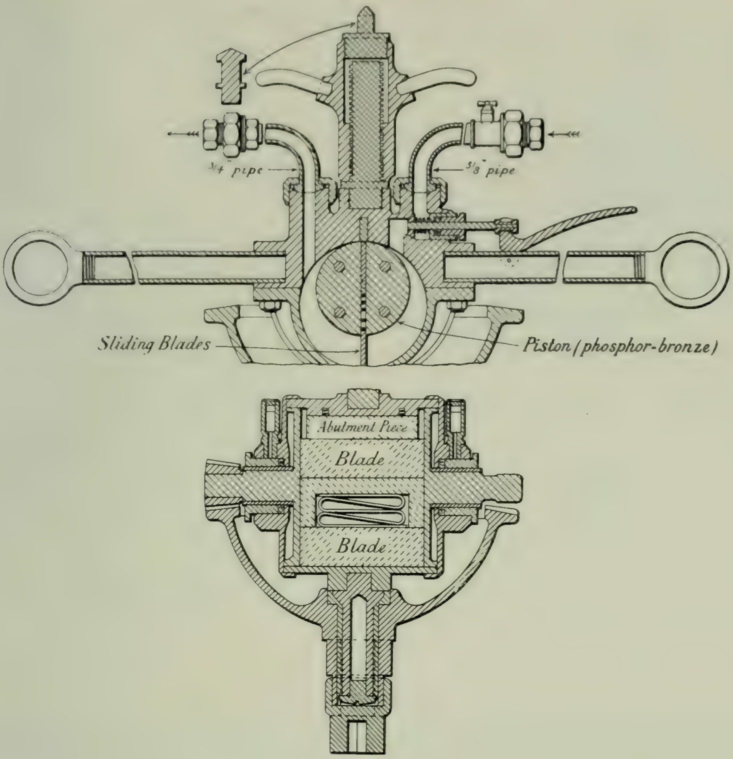
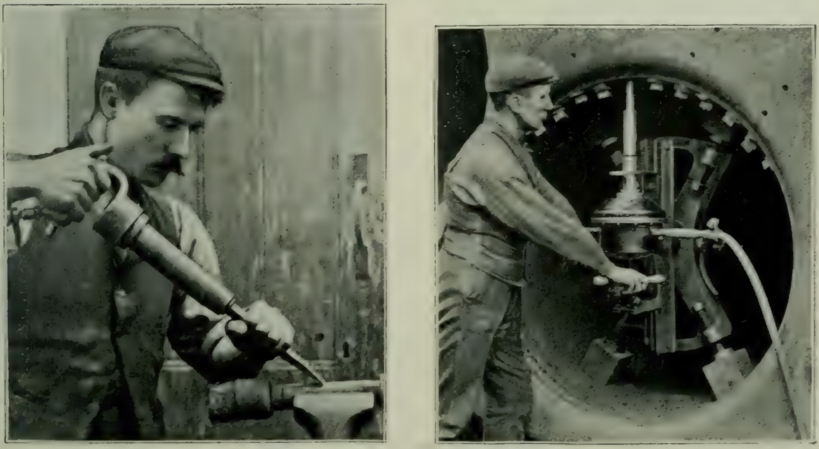


Fig. 53. *Portable Tools in use.*



PORTABLE PNEUMATIC TOOLS. *Plate 28.*

Fig. 54. *Chain Hoist.*

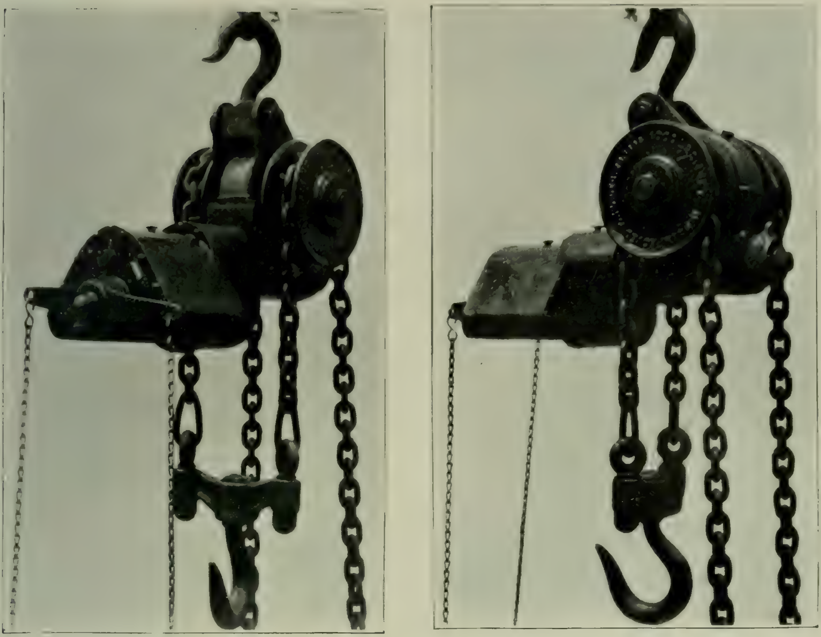


Fig. 55. *Flue Rolling.*

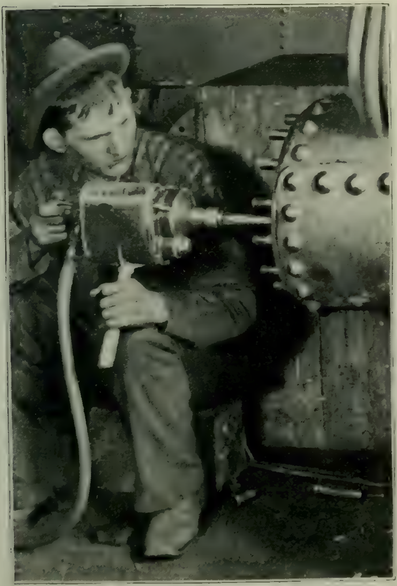
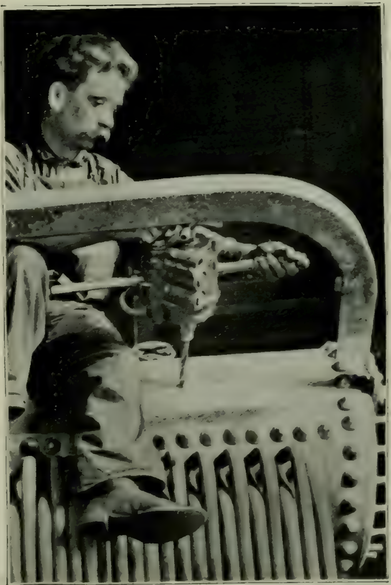


Fig. 56. *Drilling.*



The Institution of Mechanical Engineers.

PROCEEDINGS.

April 1900.

The April Meeting was held at the Institution on Thursday, 26th April 1900, at Eight o'clock p.m. The chair was taken by J. Hartley Wicksteed, Esq., Vice-President, in the absence of the President, Sir William H. White, K.C.B.

The Chairman regretted to announce that the President was unable to be present. He had been ordered to take complete rest, and had gone abroad for a month or two. Sir William however had been active in the interests of the Institution, and, from remarks in the Paper about to be read by Professor Hele-Shaw, it would be seen that that Paper was largely due to his interest in the subject. They all hoped to see him soon restored to his usual health.

The Minutes of the previous Meeting were read, approved, and signed by the Chairman.

The Chairman announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following seventy-one candidates were found to be duly elected:—

MEMBERS.

Anderson, Eugene Ernest James,	Ripon.
Boyd, Charles Arthur,	Preston, Lancs.
Calastremé, John Carlos,	Buenos Aire
Calthrop, Everard Richard,	London.
Crosta, Lorenzo William,	Nottingham.

Dean, Frederic William Charles,	Woolwich.
Ferranti, Sebastian Ziani de,	Manchester.
Graham, William Vaux,	London.
Guest, James John,	Birmingham.
Harrison, Campbell Grove,	Birmingham.
King, Charles Philip,	London.
Lupton, William Walter,	Leeds.
Northey, Percy Wilbraham,	London.
Oldham, Thomas,	Dukinfield.
Pajeken, Julius F.,	Berlin.
Parry-Jones, Richard,	London.
Pillai, Velu Pillai Devasikhamani,	Madras.
Taggart, William Scott,	Düsseldorf.
Taylor, Edward Brough,	London.
Upward, Alfred Réné,	London.
Watchurst, Charles Leese,	London.
Watney, Thomas Savile ,	Leeds.
Whitehead, Arthur,	London.
Wilson, Henry,	Maryborough, Queensland.

ASSOCIATE MEMBERS.

Anderson, Athol Lancelot,	London.
Aughtie, Herbert,	London.
Barber, Edward Whitley,	Manchester.
Bell, Charles Sever,	London.
Bentley, Thomas Sims,	London.
Carrod, Henry,	London.
Carstairs, Gilbert Langlois,	London.
Cattell, William,	Newport, Salop.
Cave, Henry,	Coventry.
Chorley, Richard,	Stockport.
Drewitt, William Henry,	Paisley.
Fiegehen, Edward George,	Bedford.
FitzHerbert, Arthur Hugh Francis,	London.
Fripp, Steuart, Jun.,	Edinburgh.
Garland, Frederick Joseph,	Birmingham.

Gilling, Arthur Hewitt,	Wolverhampton.
Graham, Walter,	Greenock.
Haskew, Frederick John, Jun.,	Birmingham.
Ito, Kumezo,	Nagasaki.
Jennings, Frederick William,	London.
Main, John Palmer Scott,	East Fremantle, W.A.
Mate, Walter Edwin,	London.
Palmer, Benedict Joseph,	London.
Petter, Ernest Willoughby,	London.
Plant, David Thomas,	London.
Rofe, William,	London.
Schutte, Francis Albert,	London.
Strong, Alfred George,	Bristol.
Tottle, Edward George,	London.
Watson, Richard,	London.
Wellington, John Morecraft,	London.
Wright, Isaac Henry,	Keighley.
Wyld, William,	Wednesbury.

GRADUATES.

Broughton, Harold,	Huddersfield.
Falconer, Edward Alaric,	London.
Faulkner, Vivian,	Walton-on-Thames.
Godwin, John Archibald,	London.
Gulliver, Gilbert Henry,	London.
Hill, Walter Hereward,	London.
Lupton, Norman Darnton,	Leeds.
Marshall, Alfred Turner,	Cambridge.
Michell, William Henry, R.N.,	London.
Murdoch, Alexander Gemmell,	London.
Newton, George Henry,	Bradford.
Parlby, Valentine,	London.
Soyres, Bernard de,	Bristol.
Taite, Geoffrey Charles,	Cambridge.

TRANSFERENCES.

The Chairman announced that the following five Transferences had been made by the Council:—

Associate Members to Members.

Abady, Jacques, ...	London.
Ambler, Frank, ...	Maceio, Brazil.
Bentley, Wallace, ...	Halifax.
Meek, John, ...	Coventry.
Watson, George, ...	London.

The following Paper was read and partly discussed:—

"Road Locomotion;" by Professor H. S. Hele-Shaw, LL.D., F.R.S., *Member*, of Liverpool.

The Chairman said that latterly the Institution had begun its meetings half an hour later, and left off something like half an hour earlier than it did in the good old days, but there were more meetings than formerly, and it was more practicable, if necessary, to adjourn the discussions. On the present occasion a very exhaustive Paper had been prepared by Professor Hele-Shaw, to do thorough justice to which would take up nearly the whole of the evening and he had represented to Professor Hele-Shaw that, as the whole Paper would be printed in the Proceedings and would be available for members to refer to, and as a great deal of the matter in the Paper was chiefly valuable for reference, he might now give merely an abstract to afford the members an opportunity of contributing their experience and of having a chance of obtaining replies from the author.

The Meeting terminated shortly after Half-past Nine o'clock. The attendance was 172 Members and 143 Visitors.

ROAD LOCOMOTION.

By Professor H. S. HELE-SHAW, LL.D., F.R.S.,
Member, of Liverpool.

There are strong reasons for thinking that the subject of mechanical propulsion upon common roads has now reached a point when it deserves the very careful consideration of mechanical engineers. The idea of bringing the matter generally before the Institution for discussion is due to our President, whose far-reaching judgment will be admitted by all.

The title of this Paper must be admitted to be very comprehensive, but it seems that what is needed at this time is a discussion of the general principles of the engineering features of the question, rather than a detailed description of any particular system.

For many years the uses and importance of the traction engine have become more and more recognised, and its possibilities in connection with the present war have quite recently been brought very strongly before the public. This engine, the work of which covers only a portion of the field for mechanical propulsion on roads, has been very fully dealt with before this Institution and elsewhere, and it will be in the first place instructive to consider what has led to a general revival of a movement for lighter road-locomotives which about seventy years ago, in the days of Hancock and Gurney, reached a point that for a time appeared to be leading to permanent results of the most important kind, but which ended in complete failure. In one sense this revival is undoubtedly due to the passing of the Locomotives on Highways Act in 1896, previous to which, for more than twenty years, a law had existed, popularly known as the "Man with the Red Flag"

Act, which made it impossible for any self-propelled vehicle to proceed at a rate of more than four miles an hour. The immediate cause of the passing of this Act was the attention aroused in this country by the successful introduction of the motor vehicle for purposes of pleasure in France, where the red flag was not at any rate used specially for obstruction on highways. This freedom from legal restriction enabled an enterprising paper, "Le Petit Journal," to organise in 1894 a trial of motor vehicles between Paris and Rouen, which was so successful as to lead to one on a larger scale between Paris and Bordeaux over a distance of more than seven hundred miles. These trials proved conclusively the great possibilities of motor vehicles, and attracted much attention in this country, where after the first exhibition and trial in England, which was originated by Sir David Salomons in 1895 in the grounds of the Local Agricultural Society at Tunbridge Wells, successful measures were taken to obtain a more enlightened legislative treatment. We must however look deeper for the real causes of the present movement, which can be traced to the gradual feeling amongst all classes of the community that modes of transport both for purposes of pleasure and business on the roads had not kept pace, or indeed had made little progress at all, compared with the great changes which had been effected in speed, comfort and convenience, in the direction of locomotion by rail.

Mr. Samuel W. Johnson, speaking of the progress of railways in his Presidential Address* before this Institution, showed that in thirty years the annual train-mileage had increased from 200 millions to 350 millions, and remarked that "Our iron roads are the arteries and veins of the nation." Pursuing this very true and striking analogy farther, it may be said that the capillaries and smaller blood vessels are in their way just as important as the larger veins. Now while the railway arterial systems have developed enormously and satisfactorily, there is still much room in present modes of collecting and distributing goods for improvements, which would materially benefit the trade and commerce of the country.

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* Proceedings, 1898, page 149.

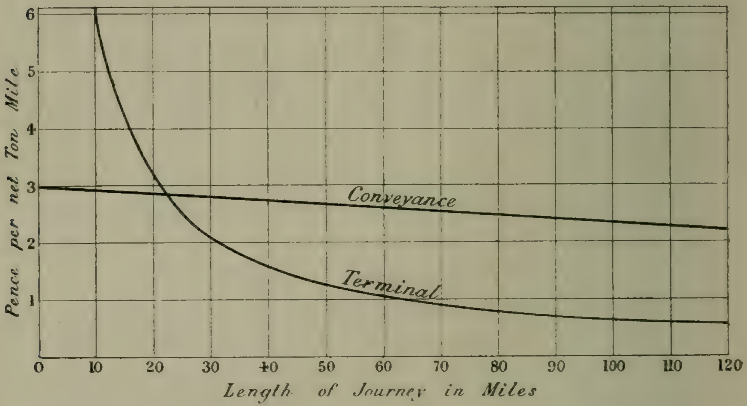
Railways are undoubtedly the cheapest system of land carriage for long distances, but there is a minimum distance below which the disproportion between haulage and terminal charges operates to their detriment. This feature of railway transport and the serious consequences of "breaking bulk" are exhaustively dealt with in an interesting and important report published in 1898, by the Special Light Railways Committee of the Liverpool Incorporated Chamber of Commerce, in which report it is made evident that Liverpool in particular suffers from these causes, and what is true of Liverpool is probably true of other great commercial cities. Cartages and terminals exceed the haulage charges over short distances by rail, whilst they become only a very small percentage of the whole when the distances are considerable. It must be obvious that a motor vehicle, which can travel from any one point to any other, which absorbs the short cartages into one straightforward journey, and which absolutely eliminates railway terminal charges, has a wide and promising scope for application. Mr. Alfred Holt, one of the leading shipowners of the country, has for many years urged the necessity of obviating these terminal charges, concerning which he states that the matter of handling is a "giant, and the transport a dwarf, and the giant is daily growing larger, and the dwarf smaller."

The relation between these two charges may be shown in a very striking manner by plotting the terminal and conveyance charges, worked out in pence per net ton-mile taken from the Government Blue Book of 1892, dealing with the rates and charges, and is given in Fig. 1 (page 188). This curve shows clearly that up to 40 miles there is a field for a system of conveyance in the working of which terminals are not incurred, and it will be at once appreciated by engineers.

Apart from these considerations, there can be no doubt that with the rapid means for communication of ideas by telegraph and telephone, and of passengers and goods by means of the railway, the general want is felt of a more speedy means of transport by road. The great improvements which are needed in our road traffic have been set forth by Major R. E. B. Crompton, R.E., at present in South Africa, and one of our old Members, in a Paper read by him before the Automobile Club, in which he clearly shows the vast and beneficial changes that the general introduction of the motor vehicle would effect in the relief and expedition of traffic in our cities, and especially in the metropolis.

Nor must the hygienic considerations be overlooked. This subject has been ably dealt with by Mr. E. Shrapnell Smith, Honorary Secretary of the Liverpool Self-Propelled Traffic Association, to whom the author is indebted for valuable assistance in many points dealt with in this Paper and particularly in connection with the final section. In his Paper, read before the Congress of the Sanitary Institute at Birmingham in 1898, he points out that with motor vehicles, not only will our streets be less offensive, especially in summer weather, but exposed food stuffs will less frequently afford a *nidus* for organisms conveyed by disseminated particles from the roads; and further, that the disintegrating effect of the horses' hoofs, which accounts for most of the dust of summer and the pasty slime of winter, will be to a great extent obviated. The sanitary advantages of the motor vehicle have also been recognised and strongly urged by many medical officers of health and surveyors to municipal and urban councils. This shows, then, what forces are at work urging us, both for light and heavy traffic, in the

Fig. 1. *Relation between Terminal and Conveyance Charges on Railways.* (Classes 1 and 4.)



direction of utilizing more efficiently and with mechanical power the 100,000 miles of road which we possess in this country.

From this side of the question we naturally turn to consider the difficulties of the problem, and it must at once be admitted that these difficulties are very great. The author has frequently seen the subject referred to as a question of mere mechanical detail, and the progress of the railway locomotive mentioned as a proof that these mechanical difficulties will be easily and rapidly overcome. Moreover, the whole blame for small progress made, and for previous failure, is often thrown upon restrictive Acts of Parliament. The truth is that the argument of the railway locomotive, so far from giving any grounds for the hope of an easy solution of the problem of road locomotion, really tends in the opposite direction. In the first place, railways are one of the most striking examples of the nature of mechanical progress first pointed out by Reuleaux, that machines became more and more perfect as their restraint by what he called "pairing" was more completely effected, *i.e.*, as the mechanical boundaries compelled the parts to move with more certainty under required conditions. The provision of a suitable track, upon which the train moves and by which its motion is guided, is the real secret of railway development. Hence it is that with a steel wheel rolling upon a hard smooth track, a continuous increase of weight, and of tractive force, together with increase of speed is enabled to be obtained. The conditions of the historical "Rocket" were a weight of six tons, a speed of from 20 to 30 miles an hour, and a load of twenty tons, while the modern locomotive and tender together weigh one hundred tons, having a speed of over sixty miles an hour, and drawing a load of three hundred tons. Now this result has been obtained by increasing the number of wheels, until the locomotive and its tender may have the weight distributed over from sixteen to twenty wheels, each resting upon a hard smooth surface of contact, whereas the motor vehicle, at any rate at present, is limited to four wheels, which have to run upon an uneven surface which, if it is hard, intensifies the action of shocks and vibrations, and if it is soft, causes an enormous amount of resistance. The load thus being on four wheels, both this sinking and shock are magnified as the load is increased, and therefore inventive effort has been naturally almost entirely directed to lightening the working parts for obtaining a given power, and this correspondingly diminishes the tractive adhesion which is a necessary feature for successful working. In short, the conditions of the problem are such as to involve improvement exactly in the opposite direction to that in which the railway locomotive has been successfully developed.

No doubt the progress of invention will ever increasingly enable a greater amount of power from a given weight of motor to be obtained, but the surface to be moved over, which is the real difficulty of the road locomotive, will remain the chief factor of the problem.

The *First* section of the Paper is therefore devoted to the mechanical problem of the *behaviour of the wheel upon the road*, and the progress which has been made in this direction.

The *Second* section deals with *Steering* and *Turning*.

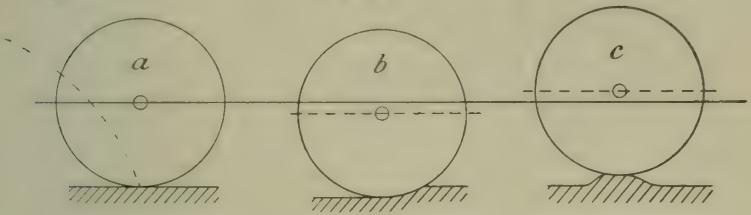
The subject of *Motive Power* is treated in the *Third* section, which is divided into internal combustion motors or oil engines, external combustion motors (steam) and electrical motors. In this section *Transmission and Gearing* are briefly dealt with.

Finally, a summary is given of the results which have been obtained, and certain general conclusions, together with Appendices containing some notes and Tables.

I. PROBLEM OF THE WHEEL ROLLING UPON A ROAD.

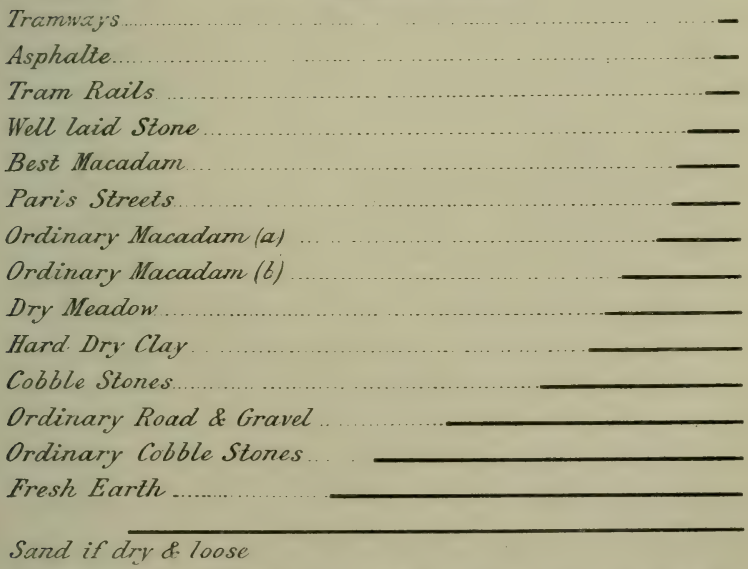
When a wheel with a hard rim rolls upon a level hard surface, every point upon the wheel follows a curve as shown in Fig. 2, *a*, and since each point on the tyre comes in succession perpendicularly upon the surface beneath, there is no appreciable resistance to the motion. When, however, the surface beneath is either soft, Fig. 2, *b*, or irregular, Fig. 2, *c*, the wheel no longer rolls in the same way, and the invaluable properties which it possesses are in a greater or less degree destroyed.

FIG. 2.



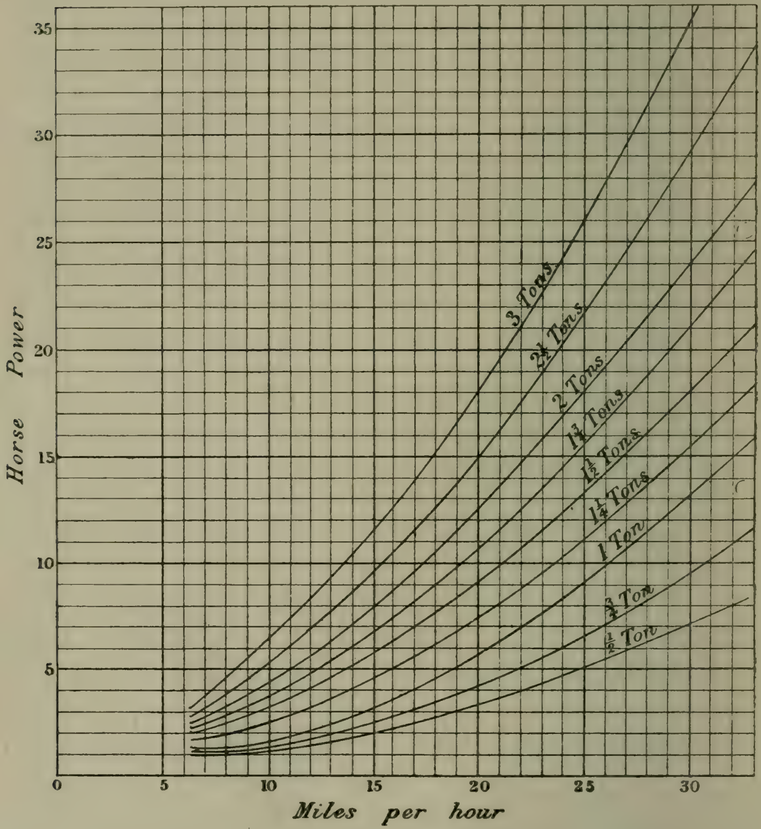
Now it is difficult, from any data at present available, to separate the amount of resistance respectively due to each of the two foregoing causes. But in Fig. 3 are plotted, from Telford and Babbage's data, the resistance to traction on roads of various kinds, and here it would appear as if a soft road involved greater resistance than an irregular one, and was more to be considered.

FIG. 3. *Resistance to Traction.*



The truth is that, when we are considering the question of the motor vehicle, the opposite is the case, for while the amount of the resistance due to the softness of the road remains practically the same as the speed is increased, the resistance due to obstacles which cause shocks and vibrations rises rapidly. MM. Bovaine et Julien in their Tableaux Numerique Graphique, have investigated the horse-power up to speeds of 50 kilometres (31 miles) an hour for varying loads. It is not necessary to reproduce their numerical investigations, but the series of curves which the author has translated into English

FIG. 4. *Horse-Power Velocity Curves.*



measures, Fig. 4, indicates clearly the great increase of resistance as the speed increases. Now it must be remembered that it is not merely the increase of resistance itself that becomes serious, but that the vibration which occurs tends greatly to destroy the structure of the motor vehicle, and makes the problem of keeping in working order the machine parts which it will be seen are necessary for automatic action, increasingly difficult.

Mr. John Brown,* of Belfast has invented an instrument, which he has called the "Viagraph," with the object of obtaining autographic records of the surface of roads. The use of this instrument indicates in a remarkable way the vibratory effects produced according to different states of roads of nominally the same character, and the curves which he has given of macadam roads in various parts of the country show remarkable and instructive differences. The city engineer of Liverpool, Mr. J. A. Brodie —who is using one of these instruments—has kindly taken, specially for this Paper, a series of curves which are reproduced on Plate 29. From these diagrams will be seen the difference in the character of vibration on asphalte and wood pavement compared with that on sets or macadam road, and shows to what different influences a motor vehicle may be subjected when it has to run indiscriminately upon these various kinds of road, unless some special provision is taken to counteract such influences. Fig. 5 gives a good illustration of the severe effect produced by a bad crossing. Now obviously the remedy for shocks is a means of causing the vehicle and its load to ride over the obstacles without being lifted bodily; since a reference to Fig. 2, *c* (page 191), shows that a lifting of wheel and axle must take place unless the unevenness of the road is destroyed by being pulverized or removed, and this lifting, which amounts to a change of direction of the vehicle and its load, must be accompanied by shocks and consequent loss of power. Springs under the body of the car are the natural method of achieving this result, since even if the wheel rises, the springs give so as to allow the main body of the load to pass onwards over the obstacles without being lifted bodily. But even with springs, the periphery of the wheel has to sustain a shock which causes noise and destruction of the wheel itself, and the best result is obtained by placing an elastic medium between the wheel and the road.

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* Proceedings, Belfast Natural History and Philosophical Society, 1899.

More than fifty years ago, a brougham was running in London with pneumatic tyres which were the invention of an engineer, Mr. R. W. Thomson.* This invention did not attain a practical success at the time, for reasons so well understood by engineers, viz., that the mechanical appliances and materials available at that time did not enable the inventor successfully to cope with the practical difficulties in the way of its commercial construction. Since its revival in recent years, it has already played such an important part in road locomotion, and is probably destined to play a much greater part, that a few facts concerning it may well be brought forward. The action of the pneumatic tyre is really two-fold; it not only interposes the desired elastic cushion between the irregular road and the vehicle, but it does so by a continuous spring of compressed air, extending round the periphery of the wheel. This air, when once compressed by the load being placed upon it, absorbs—so to speak—the obstacle with only a temporary deformation of the elastic covering, so that no further work is done in the compression of the main spring itself. Photographs have been taken by the author of a pneumatic-tyred wheel passing over obstacles of various kinds, and it can be seen that, even allowing for a certain amount of preliminary compression upon the flat surface, how small a distance the load resting on the axle has been raised, and that the idea involved in the expression "absorbing an obstacle," when the obstacle is a small one, is practically correct.

Many measurements have been made to compare the resistance to motion of a hard tyre with that of the pneumatic, but these are not very useful unless taken at varying speeds, since it is when the speed is increased that the differences become most marked. The best and most instructive results are those given by M. Michelin in a Paper read before the French Society of Civil Engineers a few years ago.* These trials were conducted for all kinds of loads, in all kinds of weather, upon varied kinds of roads and at various speeds, and though it would require a separate paper to deal with them adequately, the general conclusions may be briefly summarised as follows :—

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* See Abridgments of Specifications, 1625–1866, No. 10,990, 1845.

(1.) The force required for the pneumatic tyre increases very little from walking to trotting, while that absorbed by an iron tyre perceptibly increases with the speed.

(2.) The advantage of the pneumatic over the iron increases rapidly as the speed increases. Taking 100 as the force required for the pneumatic tyre and iron tyre at a slow speed, the resistance of the iron tyre increased at an ordinary trot to 126, and at a quick trot to 164, and probably if the matter had been investigated for ordinary speeds of an autocar, the relative resistance of the iron tyre would have been found to rise even more rapidly.

(3.) The solid india-rubber tyre is better than the iron-tyred wheel in certain cases, especially at the trot, if the surface be sticky, very irregular, or covered with snow ; but it becomes inferior to iron if the surface be hard and smooth. It never gives a much better result than the iron wheel, and it always remains vastly inferior to the pneumatic. On the other hand the pneumatic is fifty per cent. better than the iron tyre.

As M. Michelin remarks, "It is a curious thing, but we have known many people who have only seen pneumatic tyres, and who have never tested them, affirm that these thick tyres must drag heavily. It is specially on bad ground, in mud, in snow, that the advantage of the pneumatic is made clear." It is interesting to note as confirming this statement, that it was recorded in the automotor journals that during the recent heavy snow and bad weather, automobilists were able, to their great delight, to use their vehicles freely, the pneumatic tyres appearing to be almost unaffected by the bad state of the roads. In addition to the numerical results obtained by M. Michelin, a series of graphic records were obtained from the body of the vehicle, which explain to the eye at once better than any figures, the reason of the satisfactory results obtained by the pneumatic tyre. One or two of these are reproduced on Plate 30, in which the curve traced by the vehicle with iron tyres meeting an obstacle is shown by a full line, while the behaviour of the vehicle fitted with pneumatic tyres is shown by the dotted line. In these curves, instead of the sharp jump indicating a violent shock and loss of power which occurs when the iron tyre meets an obstacle, it is evident that the pneumatic carries the vehicle over with an easy and gliding motion. This, which is evident in the small obstacle, Fig. 14, is much more so in the case of the larger obstacle, Fig. 15, while when the three obstacles are interposed, Fig. 16, the beneficial effect of the pneumatic tyre is very remarkable.

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* Translated and published in a series of articles in the "Autocar," commencing 15th August 1896.

For heavy traffic, when it is remembered that the load has to be concentrated upon the point of contact on the periphery of four wheels, it is no wonder that the wheels have hitherto been almost entirely made with iron tyres. At the first Liverpool trials of heavy motor vehicles great trouble was experienced with the wheels, which had been made in the best possible manner for ordinary vehicular traffic. In almost all cases the wheels showed signs of the severe stresses and shocks to which they had been subjected, and some of the vehicles utterly broke down in consequence. The construction of the wheels themselves has latterly been the subject of much careful design on the part of makers of motor vehicles, the wheels having necessarily not only to bear the actual load, but to transmit tractive force from the motor. Plate 31 shows some of the wheels which have been specially designed by the makers of motor vehicles. These wheels show in each case the arrangements for driving, and this feature is a vital part of the design of the wheel. The iron portion has been blocked in to indicate which is metal and which is wood, and the nature of the construction will be evident without any detailed description. It may be pointed out that Messrs. Coulthard use a wheel entirely of iron, Fig. 20, which seemed to give very satisfactory results at the Liverpool trials, where it must be noted that part of the 40 miles run was over a road paved with cobbles of the sort well known in certain parts of

Lancashire, affording a test scarcely to be surpassed in severity. The last wheel shown on the series is that of Messrs. Bayley which differs from the other driving wheels in the important detail of being coned or dished, Fig. 22. A great deal might be said in considering whether the advantages of a coned wheel for heavy traffic are not more than counterbalanced by the constant tendency of such wheels to run outwards, since when the axles are not horizontal, they can only be made to run in a straight line by a certain amount of slipping constantly going on at the tyre, and a constant outward drag upon the axle. Messrs. Bayley's wheel, however, worked very well at the Liverpool trials and subsequently, which is after all the main point to be considered. There is another important peculiarity, and that is that the spur wheel attached to the driving wheel is annular, and is driven by an internal pinion. This affords considerable protection from dust and dirt, and enables the outside of the annular wheel to be used very effectively as a brake wheel encircled by a band brake. The spokes are of oak with ash felloes, the iron tyre being 5 inches wide. In consequence of the new design and special construction of the wheels adopted by most of the makers, they were enabled to stand much better at the second Liverpool trials, but even in the second Report, the judges wrote in their special conclusions as follows:—"The wheels and tyres were generally efficient, but concentration of heavy loads upon the present small area of wheel contact is a serious difficulty in the problem of goods transport by motor vehicles, and constitutes the chief mechanical cause of the slow progress made."

Quite recently one or two makers have been appreciating the great difficulties of this question, and have tried to adopt solid india-rubber for tyres, and Fig. 21, Plate 31, shows Messrs. Simpson and Bodman's wheel, in which the india-rubber is shown cross-hatched in section, and from which they have obtained very satisfactory results. The action of the solid tyre, however, differs in a most important respect from that of the pneumatic, namely, that although deadening shocks, there must always be a great loss of energy consequent upon the continual expansion of the different parts of the substance itself, which is totally different from the behaviour of the air-cushion in the pneumatic tyre. In Michelin's experiments the solid india-rubber showed itself always greatly inferior to the pneumatic tyre (page 195), and under some circumstances inferior to the iron tyre itself. It was put into competition with the pneumatic tyre in the early days of the cycle, and in that competition has disappeared for ever. The same process of competition seems to be going on in the case of the light motor vehicle, though the difficulties are more than proportionally greater as the load upon each tyre increases. In this country the Dunlop Company have been for years at work improving the tyres for motor vehicles, and the section of their latest production is shown on Fig. 10, Plate 30. It will be seen that the tread has been made thicker where the greatest wear takes place and where there is the most liability to puncture, while the external circular form is retained. It is found necessary to use the very best india-rubber for the external portion, in order to admit of the necessary deformation, whilst the inner part of the body of the outer tube has to be strengthened by means of layers of woven canvas insertion. The steel rim on the wheels holds the two enlarged edges of the outer covering of the tyre so that when the inner tube is inflated the tyre is held in its place without the necessity for any internal wiring or fastenings. Special machinery is required to make this tyre at all cheaply. This Messrs. Dunlop are now putting down, and it is hoped that the pneumatic tyre for light motor vehicles will before long be obtained at prices which will enable it to be universally placed on such vehicles.

Fig. 11 shows a section of the Michelin tyre, and it is interesting to note that M. Michelin, who, as he naively remarks, commenced his research on the subject " with the object of proving that the English did not now possess the monopoly for making pneumatic tyres," has now succeeded in producing tyres that, it is only right to say, are preferred by many users of motor vehicles in this country. This is not so surprising when it is remembered that the French have been far ahead of us in the production of light motor vehicles, and the demand for suitable tyres for such vehicles has been very keenly felt. The Callus, which is also a French tyre, is shown in Fig. 12, and is seen to be almost identical with the Dunlop tyre, except that in the important matter of tread there is not so much extra thickness allowed, and it is obvious that the Dunlop tyre would carry a much greater load as well as have a longer life.

The Goodyear, Fig. 13, which is an American tyre, differs from the three preceding ones in that, like most American tyres, there is no inner tube, neither does it depend at all for attachment to the rim by inflation, but is held on by means of small screws, the nuts for which are inserted in the body of the tyre. There is not much appreciable difference of thickness for the tread of this tyre, which is circular in section, but it is sufficiently thick for all practical purposes.

With heavy traffic, where noise and vibration are not so fatal to success as in the case of pleasure vehicles, the importance of having pneumatic tyres cannot be said to be so great. On the other hand it becomes of more importance to carry if possible a heavy load easily over an obstacle without shock than a light one, as the destructive effect on the vehicle of the inequalities of the road is naturally greater. This problem of spring wheels in connection with road locomotion is one which has exercised makers of traction engines for many years, but ten years ago it was stated,* "The exertions of inventors during the last quarter of a century seem to have been inadequate to the production of a wheel with elastic tread, which will satisfy all the complex and most difficult conditions governing the use of traction engine wheels. Not a few of the most eminent and successful makers of traction engines have abandoned elastic wheels altogether, and resorted to springs between the main axle and the engine, and they have, on the whole, been successful." In spite of this, however, when one looks at the original design of Thomson's wheel in his patent, one cannot help feeling that he understood what was required, and that although the practical difficulties may be great, there are no mechanical impossibilities in the production of a pneumatic tyre for the very heaviest vehicular traffic. With any existing system, in which four wheels are used, the problem is a difficult one, because of the concentration of the loads upon such a limited area of support. The pneumatic tyre however extends this area of resistance by yielding, so that the area in contact is much greater than in the case of an iron-rimmed wheel, especially when running over sets or hard ground. Beyond this, it is quite conceivable that, just as in railways the number of wheels has been largely increased until a modern bogie carriage has commonly twelve wheels supporting it, it may be found economical to support a motor vehicle also upon a much greater number than at present.

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* "The Engineer," 12 December 1890, page 469.

II. STEERING AND TURNING.

Steering.—The steering of motor vehicles is evidently a very important part in their design, and it may at once be said that with one or two exceptions, the great majority of motor vehicles are steered upon the principle which was invented by Ackermann as long ago as 1818, the leading feature as stated in his own words being that a vehicle "will turn within a small compass and with safety, because the wheels do not materially alter their bearing upon the ground when they are placed in the greatest degree of obliquity." The essential principle of the Ackermann system consists in replacing the pivoted fore carriage of an ordinary vehicle which has one axle for the two wheels, by two short pivoted axles each carrying one of the steering wheels. The conditions of correct running of the wheels are that when they are turned, their normals intersect on a point on the line of the axles of the driving wheels. In the Ackermann invention, this is obtained approximately by a pair of short levers inclined either inwards or outwards to the longitudinal direction of the vehicle. Fig. 23, Plate 32, shows a Daimler frame in plan in which the short levers are inclined away from each other, the connecting bar between the two being in front of the axles of the steering wheels, whereas Fig. 24 shows the plan of the Clarkson and Capel steering arrangement in which the levers are inclined towards each other, the connecting bar being behind the axles of the steering wheels. The other details of the steering arrangement are obvious without further explanation. In the case of wheels steered on this plan, it is evidently of great importance to have the wheels coned so that the point of support of the wheel is as nearly as possible under the pivot about which each of the short axles turn. The reason for this is clear from the drawings, since the line of stress now comes more directly under the pivot which is vertical, and thereby largely reduces the bending effect or leverage upon the pivot. At the same time this coning makes it very much more difficult to effect the steering when the vehicle is being manœuvred, and especially when standing still, as the wheel tends to run round the point where the direction of the short axle meets the ground, and anyone who has watched the effort required on the part of the driver of a heavy motor wagon under the circumstances, even when the steering wheel transmits motion through gearing, will be at once convinced of the reality of this objection. Although the Ackermann invention is found to give sufficiently correct results in practice, it only approximately fulfils the required conditions, and in extreme positions of the wheels the axles may be very far from their correct positions. Mr. Davis has applied a geometrical principle in his steering gear, which gives absolutely accurate movement of the wheels for every position of the steering lever. The suitability of the two short pivoted axles for steering purposes is dealt with in the Appendix reports. Fig. 25, Plate 32, represents the plan of the fore wheels of the carriage, A_1 A_2 being the centre line of the driving wheels, B B the axes of the steering wheels in the initial position. If the directions of the short levers D D are always caused to intersect in the line C_1 C_2, which is an equal distance in front of B B that A_1 A_2 is behind it, then the normals of the wheels will themselves always intersect in the same point of the line A_1 A_2. Thus the directions of the dotted position of the levers are shown intersecting C_1, and the normals of the wheels simultaneously intersect each other at the point A_1. This condition can be effected by causing the two levers to be actuated by sliding straight guides, the bar connecting which is made to move parallel to itself, and at an equal distance from the line of the pivots upon which the short axles turn. Fig. 25 shows the plan of the actual arrangement in which the levers D D are enclosed in the sliding tubes E E, which are actuated by the guide bar F, the dotted lines showing the various parts in one extreme position of the steering wheel.

Turning.—There is another feature of the motor vehicle to which care and attention has to be given, and that is the provision of some differential gearing for the driving wheels when any turning movement of the vehicle takes place. The operation of differential gearing, or jack-in-the-box as it is commonly called, has long been understood by engineers, but a number of forms have been designed to meet special requirements of the motor vehicle. The ordinary form of differential motion consists essentially of three bevel-wheels, the middle one being the driver actuated from the motor. Now when the vehicle is turning a corner the inner driving-wheel tends to lag behind the other one, and hence the resistance is not the same on each wheel. Now since the two bevel-wheels on either side are connected respectively at equal speed ratios with the two driving-wheels, it is clear that one will be allowed to run round more than the other, and so the two driving-wheels can accommodate themselves to the required conditions. The Beeston Company have a very ingenious arrangement by which an epicyclic train of spur-wheels and pinions is employed to effect the same result.

III. MOTIVE POWER AND TRANSMISSION.

Although the action of the wheel upon the road has been referred to as being at the root of the whole problem, the question of motive power attracts the most interest and gives the greatest scope for inventive talent as well as most trouble in actual use. The three kinds of motive power at present adopted, viz. oil, steam, and electricity, have fairly well-recognised spheres of operation, although this must be regarded as by no means a final condition of things, or giving a limitation to the employment of each type of motor. Thus, although at present oil-engines are used for light motor vehicles and steam for heavy traffic, there are very ingenious steam motor-cars both in this country and abroad, while light oil-engines have been applied in France and also in this country in connection with heavy traffic. Moreover, there are other kinds of motive power, such for instance as compressed-air, which is being tried in America.

Oil-engines, or as we will call them internal-combustion engines, have by a process of the survival of the fittest been found so far best suited for light motors and pleasure vehicles. The cycle of the gas-engine is really complex, but these motors have been brought to a high state of perfection, so that upon being started they are found to work for long distances without any attention. If really well designed and constructed, and used with a moderate amount of care, they need little repairs or adjustment, while the objection of smell, vibration and danger from the use of light petroleum spirit with a low flash point have all been much reduced, and each year sees an increasing number of places in town and country where petroleum spirit can be obtained. Still the objections above-mentioned must be admitted to exist, and, together with the great expense of pleasure vehicles, have to a certain extent prevented their introduction becoming general. Again, an oil-engine, which has little elasticity in regard to an increased demand for power when ascending a hill, requires elaborate gearing for change of speed, which may be after a time, if not at first when the car is new, a very noisy and objectionable feature. Heavy-oil engines for internal combustion have been tried for motor vehicles, but the difficulties of starting and smell have not yet been satisfactorily overcome. In connection with this matter some recent experiments by Mr. Henry Barcroft, of Newry, who has succeeded in maintaining constant mixture and compression under varying load, promise well for the future.

Steam, or external-combustion motors, require not only a generator or boiler, but also a condenser, in addition to the steam-engine itself. The author is aware that the latter is not used with all motors, but in winter the cloud of steam which must be visible in damp cold weather at a little distance from the exhaust, even if the steam is superheated, really contravenes the Act which states, "No smoke or visible vapour must be emitted, except from any temporary or accidental cause." Steam introduces a more complicated array of pipes and fittings, and requires more attention and skill in working, but it is highly probable that such improvements will be made in connection with steam motors, that no skilled attendant will be necessary. There is already at least one steam system which is entirely automatic, whilst others are to a great extent so. It is not too early to speak as to the practical and commercial success of any of the systems using steam (*vide* Appendices), but if a condensing steam-engine, automatic in action, with a boiler which is perfectly safe from any fear of explosion, can be produced, it may safely be predicted for it that there is a great future before it, both for light and heavy traffic, as it would have the advantages of great power and elasticity, freedom from smell, and if using heavy oil or even coal or coke, would be free from the danger and trouble incidental on the employment of light oil, especially abroad. Moreover, the ease with which a steam motor can be started and stopped, and more particularly reversed, cannot be over-estimated.

Fuels, other than coal, coke, or oil, have been the matter of careful consideration by motor-car designers. The most promising of these is acetylene, which, as derived from calcium carbide, enables a much greater quantity of energy to be obtained from a given weight of fuel; but although it only requires one-fourth of the weight of calcium carbide to produce a given amount of work as compared with coke, the expense at present makes its use commercially impossible.

Electrical motors are clean, extremely convenient and simple, free from all vibration and danger, and altogether an ideal type of motor. The limitations in the use of electricity are however very serious, and will be discussed later on.

Internal-Combustion Motors.

There are six features of internal-combustion motors upon which their success more or less depends, and they are:—1. Carburettion or Carburization; 2. Ignition; 3. Starting; 4. Governing; 5. Balancing; 6. Cooling. It is impossible even to enumerate the variety of inventions on these various parts of the oil-engine, especially adapted for the motor car, and these will be found to have been recorded from week to week in the journals specially devoted to motor vehicles. Some salient points however may be stated.

1. *Carburettors, or equivalent.*—Carburettors are of course the arrangement by which air is charged with a suitable portion of spirit vapour before entering the cylinder; and they are of two chief kinds:—(1) Vaporising carburettors, by which the spirit is heated so as to insure its giving off a certain amount of vapour, when a current of air is drawn through or over it. (2) Spray carburettors, such as a float feed, by which a fine jet of spirit is drawn into a current of air at ordinary temperatures. Of course there is some difference of terminology on this subject; thus the Daimler Company state that the vaporiser or carburettor has been entirely discarded, and a new system of automatic float-feed adopted, whereas types of float feed which are similar in general principle, if not in detail, are distinctly termed "Carburettors" by respective makers. The great object of many of these contrivances is automatically to adapt the charge of air and petroleum spirit to varying conditions of load, so as to attain the greatest economy with uniformity of speed. It is obviously a matter of great importance to separate completely or atomize the hydro-carbons and mix them with the air, and there are makers who go so far as to claim an economy of 25 per cent. by the special mixing arrangements they use. The Longuemare, Huzelstein, De Dion, Daimler, and Lucas are among the best known of these mixers.

2. *Ignition.*—There are two methods of ignition, which are of course common to all gas-engines, viz., tube and electric; but we have to consider these specially in their application to motor vehicles. For a very long time tube-ignition maintained its popularity, owing to its great simplicity and comparative trustworthiness. In strong winds however, as the author can testify from experience, it was a frequent occurrence for the flames to be blown out in running, and this fact particularly led to the

invention of the Lyon and Whitmore system of ignition, which was awarded a diploma at the Richmond Show, in which, by means of spirit, a small bunch of platinum was kept white hot (inside a tube) which projected into the cylinder of the motor. Now however there seems to be a steady and certain tendency in the direction of electric-ignition. As long as the electric-ignition was limited to either primary or secondary cells, which require charging and attention, this was not the case, because, in spite of the claims made as to the number of miles the cell would run, there was no means of being sure as to the amount of the charge until it had ceased to work. Now however the magneto-electric ignition, in which the current is obtained by the revolution of the motor itself, or by turning a handle previous to starting, has removed these objections. The Simms-Bosch is one of the best known of these, and is being fitted by the Motor Carriage Supply Company to all their engines at the present time. There is an advantage however in electric ignition above all others, and that is the fact that it can be practically used as a governor, for, by advancing the time of ignition merely by turning the point of contact on the dial, the combustion of the charge can be made to take place at any point of the stroke, and hence a most effective means is found of regulating the speed.

3. *Starting.*—All starting arrangements of the oil-engine require vigorous turning of a handle in order to get an initial compression, and therefore instead of, as in the case of steam, stopping the motor with the temporary stopping of the vehicle, it is found more convenient to throw the engine out of gear. This is at present one of the most objectionable features of the oil-engine used for the motor-car, since on such occasions, owing to there being no load, it is very difficult indeed to insure perfect combustion, the impulse taking place only once in several revolutions, giving a consequent vibration to the engine, which when unloaded is very marked. It will be easily understood that when stopping for a few minutes in the street, or outside a house or shop, and particularly when only one of the passengers requires to dismount, this is an annoyance which probably tells more than everything else against the popularity of

the motor vehicle. Hence it is that various attempts have been made under the same general lines as the ordinary gas-engine, to obtain self-starters under a charge of compressed-air. Opinions of course differ as to the importance of such self-starters, and it yet remains to be seen whether their general introduction will take place, adding as it does another complication to the vehicle.

4. *Governors.*—The use of a governor of some kind for the oil-engine, which is frequently thrown out of gear with the driving wheels, becomes an important feature of the engine. The governor of the Daimler motor operates on the exhaust valve. When the engine overruns the valve-rods they are prevented from being operated on by cams; the valves are thus kept shut, which prevents a fresh charge being drawn in through the inlet valve. The peculiarity of the engine is that the valve-rods for both engines, which are always in pairs, are not each operated on at the same time, one valve-rod being first operated upon and then the other, which enables a much more regular action to be obtained. Usually, where a governor in a hydro-carbon motor is employed, the speed of the engine is regulated by either throttling the inlet valve or not lifting up the exhaust-valve. The Simms-Bosch ignition-gear already alluded to is usually actuated by a lever, thus enabling the speed of the motor to be adjusted by hand. In some cases however this invention is combined with a centrifugal governor; thus the governor can be set to any required speed, and the timing gear automatically actuated not by the more or less crude way of throttling, but by actually decreasing the number of explosions by the retardation of the time of ignition. This seems a very scientific method of governing, and is rapidly coming into favour.

5. *Balancing.*—The satisfactory balancing of the gas-engine is a much more difficult problem than that of the steam-engine. In the first place, owing to the explosions in the cylinder of the former, the piston receives a violent impulse even under the best conditions of mixture and compression, which is quite different from the behaviour of steam; secondly, steam can be regulated by admitting only a

small quantity at a reduced pressure every stroke, whereas the Otto cycle, which is practically universal, only allows the impulse to take place once in two revolutions. This necessarily introduces an irregularity in the motion, the effect of which cannot be appreciably modified on a motor-car by a fly-wheel, and accentuates any want of balance in the working parts. When the engine is in gear and the vehicle travelling at a fair speed, these irregularities are absorbed by the mass of the vehicle, but at slow speeds or when the engine is disconnected want of balance makes itself felt. The original Daimler placed the angles of the two engines nearly at 180°, and thereby mechanically effected the balancing of the reciprocating parts, although of course there was a turning couple, which was however not of great importance, owing to the two cylinders being placed quite close together. But strange to say, as progress has been made, this mechanical balance has been entirely departed from, and the two cranks of the similar engines are placed side by side, on account of the fact above-mentioned of the Otto cycle being employed, and there is found to be less vibration and generally better results, since the cranks would in the original plan be separated by angles of 180° and 540°, whereas if placed side by side they are only really separated by angles of 360° when measured by the period at which the successive impulses occur. Plate 33 shows the typical ways in which balancing is effected. Fig. 32 represents the original Daimler in which the cranks are separated, and in which the pistons are always moving in opposite directions. Fig. 26 represents the Prétot and Koch, with a single cylinder and having an Otto cycle, in which two pistons are employed moving in opposite directions (as also do the levers) connecting rods which are attached to the crank. This is in some respects a very effective method of balancing, but the increase in the number of rods is of course a serious drawback to its general introduction. In this of course, as the cranks must be separate, the twisting action on the couples is unavoidable. Fig. 27, which has been termed the "Gobron" method, has been very frequently adopted by other inventors. This effects the same end as in the previous case without requiring a number of additional levers, and is probably one of the only single-cylinder methods of balancing which entirely avoids the action of a twisting couple, the only other one known to the author is that of Hyler-White, shown in Fig. 28, which however, as will be seen from the drawing, obliges the use of spur gearing. The Henriod system, Fig. 30, really corresponds to the Daimler method; although it is not so compact, it has a theoretical advantage which becomes obvious when the crank effort diagrams are drawn out, from the connecting rods operating at different sides of the crank shaft. Fig. 29 is that of Lanchester No. 1. In order to understand the action of this it must be remembered that the two cranks are disconnected, the two fly-wheels moving in opposite directions; of course, with only a single-cylinder engine, the piston is not balanced, but as there are two connecting rods which move outwards and inwards in opposite directions, these balance each other perfectly, and by the addition of another cycle a perfect balance of the system can be obtained. Fig. 31 gives another form of Lanchester engine. Fig. 33 gives the "Monarch," and method of balancing.

6. *Cooling.*—For small oil-engines, such as are used on the motor tricycle, the cylinder can be kept sufficiently cool by radiating plates cast on the cylinder, as in the well-known De Dion motor. When the engine is increased to three-horse power and upwards, water-jackets become an essential feature of the engine. At first there were no special arrangements made to cool this water, and with severe running in warm weather a considerable quantity was evaporated in this way. In recent years more attention has been given to this subject, and by means of forcing air round circulating tanks, and the use of special coolers or radiators consisting of pipes through which the water is circulated, the pipes having a special contrivance either in the shape of very fine wire attachments so as to dissipate the heat, or of small rosettes of thin metal threaded on the pipe, a great improvement has been effected both in efficiency and in reducing the consumption of water. In the case of one of the trials at Richmond in 1899, a wagonette, carrying three passengers besides the driver, ran 50 miles in 4¾ hours with a consumption of only 2½ ounces of water. The Daimler Company are now fitting water coolers upon all their vehicles.

External Combustion (Steam).

The external-combustion motors for vehicles are up to the present entirely steam-engines, and so much has been done in recent years in developing and improving steam-engines upon a small scale, that it is scarcely possible to have any absolutely new features in the engines themselves. Thus, although there are various special details which are of interest, it is not worth while to take up time in describing the varieties of the engines themselves that are employed. On the other hand, oil-burners and boilers, as well as condensers, have in many cases been invented entirely with the object of their application in this direction, and must be, however briefly, touched upon. As before mentioned, the use of steam-engines in this country has been to a great extent limited to heavy motor vehicles, and it is a point of great interest to compare how the more important makers have arranged the distribution of the boiler, motor, gearing, tanks, condensers, &c.

The principal systems of steam-motor vehicles have been arranged for convenience of comparison upon one diagram, Plate 34, and further for convenience a uniform system of lettering (explained in the Plate) has been adopted throughout. A glance at the diagrams will show the very varied methods in which makers have distributed the essential features of the heavy motor vehicle. It will be noticed at once that all the boilers except one are placed in the front and above the car. The exception is the Musker system, Fig. 36, and this, owing to its having a horizontal boiler and a special fan or draught for the burner, by which it is enabled to do without a funnel, is placed transversely under the middle of the car. The Musker system really differs from the others in the essential feature of employing a separate auxiliary engine, which supplies air and oil for the burner in proper proportions, and also water to the boiler. The fan, as will be seen from the diagram, takes the air through the condenser in which it is partially warmed. It is obviously important to have the boiler and engine as near as possible to the main driving wheels, which are in every case the rear wheels, because, although when loaded the weight of the load is in most vehicles to a great extent distributed over the driving wheels, yet when running light, if the boiler and a fair proportion of the engine are carried upon the steering wheels, there may not be sufficient weight upon the driving wheels to provide tractive effort. A large platform area is provided by the Musker system, but at the same time it must be pointed out that when one of these vehicles is carrying its full load, the weight is not so much concentrated over the driving wheels as in the other systems, which is a point decidedly in their favour. This system has recently been fully described in a Paper before the Liverpool Engineering Society.

The next important feature of difference between the systems is in the position of the engines. In the Thornycroft & Lifu systems, Fig. 34, the engines are placed horizontally in the middle of the wagon, and the main driving wheel is driven by means of toothed gearing. This is also the case in the Musker system. The Coulthard, Leyland, Fig. 37, and Clarkson and Capel systems, Fig. 39, all have vertical engines which, by means of chain gearing operating through a counter-shaft, transmit the motion to the main driving wheel. In the Bayley system, Fig. 38, the engine is also vertical, but transmits the motion by means of a horizontal shaft placed longitudinally with the wagon, and drives a counter-shaft by means of bevelled gearing, which counter-shaft in turn drives the main driving wheel by a pinion and spur-wheel. In the Simpson-Bodman system, Fig. 35, the distribution of parts for some reasons is the best of all, and the whole arrangement is extremely neat and ingenious. In this case there are a pair of small three-cylinder engines which work separately and independently the two main driving wheels. These engines are placed at the rear of the vehicle in a convenient and accessible position, and their weight, together with the weight of the gearing, tends to increase the tractive effort of the main driving wheels when the wagon is running light. By using separate engines, the necessity for a jack-in-the-box or differential gearing is avoided. Interchangeable spur-wheels are used to transmit the motion from the engine to a counter-shaft, by means of which change of speed gear can be effected in a few minutes, and from them the power is transmitted to the main driving wheels by a powerful chain. The engines of Simpson-Bodman are very well balanced, and run so smoothly at several hundred revolutions a minute that a coin will stand upon its edge on the top of the cylinders. A full description of the Simpson-Bodman system has been recently given in the Automotor Journal.

Another important feature of difference between the various systems is to be found in the fact that the Musker, Leyland, Coulthard, and Clarkson and Capel, all use condensers, the location of which can be seen by an inspection of the various diagrams, whereas in the others the effect of superheating the steam is relied on in order to avoid the emission of visible vapour.

A full description, giving all the important details of the Thornycroft, Lifu, Coulthard, Leyland, Bayley, and Clarkson and Capel systems, will be found in the two volumes of the Report by the Self-Propelled Traffic Association on the heavy motor trials in Liverpool, copies of which the author has presented to the library.

Burners for Liquid Fuel.—The number of burners for liquid fuel which have been invented in recent years is very great, and Plate 35 represents the types of those in successful operation. An important distinction must be made between burners for light and heavy oil. For the latter, which are the burners chiefly illustrated, special means must be taken to heat in each case the petroleum in order to vaporise it, whereas with a light spirit, vaporization, although necessarily effected on the same principle, is a far less difficult matter, and may be said not to involve the risk of carbonising the products. It is well worth the application of considerable effort and ingenuity in devising means for the use of heavy oil, as it is relatively much cheaper and safer to use. For internal-combustion engines, with one or two exceptions, light oils are invariably used on account of their cleanliness and ease of vaporization, while, on the other hand, for external combustion, in which petroleum is employed to heat the boiler, there are only one or two examples in which light spirit is employed. The Longuemare burner, which is shown in plan and elevation in Fig. 40, Plate 35, is largely used in France, and consists of a row of coils through which the spirit is brought, from which it afterwards passes down by a pipe B, through a needle-valve which is regulated by a wheel C, that can be operated by the driver. The Lifu burner, Fig. 42, of the Liquid Fuel Company, late of East Cowes, has worked very successfully, and consists of a casting D, in the tortuous passages of which the petroleum is made to circulate ; it thus becomes thoroughly vaporised, since the casting is placed in the body of the flame which issues at E. F is an air cone, allowing the proper proportion of air to mix with the vapour issuing from the needle-valve, shown in section, and is self-regulating. A peculiar feature of the contrivance is an igniter G, filled with fire-brick, which is also maintained in a red-hot condition by the flame, so that in the event of the flame being extinguished suddenly, it is immediately re-lighted from the white-hot fire-clay acting as a temporary reservoir of heat.

In neither of the foregoing is any attempt made to regulate the air-supply. This is an important matter in order to insure perfect combustion, and arrangements are made for doing so in both the Clarkson and Capel and Musker burners. In the former, which is shown in Fig. 44, this is in a sense done automatically. The air can be regulated in quantity by altering the amount of opening of the diaphragm at L L. It mixes there thoroughly with the vapour which has been generated in the coil H, round which the flame circulates. This vapour enters the mixing chamber J, through a small needle-valve M, at the orifice K. The needle-valve is opened and closed by a lever P, which at the same time raises and lowers the larger valve N, so as to regulate the outflow of combined mixture of oil and air underneath at Q Q, the flame being baffled on the inside of a hollow nickel cone. The whole arrangement worked very satisfactorily in the Liverpool heavy motor trials.

For the burner of Messrs. Musker, which is shown in Fig. 52, Plate 37, the air is supplied by a fan which is driven by the same auxiliary engine which supplies both the water for the boiler and oil for the burner, the right proportion being thus automatically regulated. The air passes inwards as shown, through the passage J J, which is kept at a high temperature, by means of cylindrical projecting ribs, which form part of the solid ignition-chamber K. The oil, which is admitted by drops at the point L, falling upon the heated iron surface is thus vaporised and immediately mixed with the heated air. The mixing is further insured by passing through a number of holes in a perforated block M, and ignition takes place in the chamber K. The actual working of this burner is very striking, since the air being regulated in relation to the oil, the flame, instead of as in many cases varying in quality according to the oil supply and sometimes shooting forward in a long flame with a perceptible smell, is always, under the various conditions in which the author has examined it, of the same character and intensity. The conditions of ignition are always the same, although the actual size of the flame varies with the supply from the auxiliary engine.

The Leyland burner is shown in section and plan, Fig. 41, Plate 35.

The burner, Fig. 43, Plate 35, is given merely as an example of one for the use of light petroleum spirit or benzine, being that employed in what is known as the Stanley Motor Car. In this case the diaphragm at S has one side exposed to the pressure of steam from the boiler by means of a steam-pipe T. The spring V is thereby caused to regulate the needle-valve at X, by which the spirit enters by the pipe Y, and passes to the furnace under the boiler; thus the supply of spirit is regulated according to the pressure of steam in the boiler.

Steam Generators.

The two most important considerations in connection with the design of a steam-boiler for motor vehicles are, first, to have a boiler as light as possible consistent with high pressure, and secondly, to have a type of boiler which is capable of being forced so as to meet a sudden demand for an increased quantity of steam at a higher pressure. The latter point really constitutes, as has already been pointed out, one of the great advantages of steam for a motor vehicle, and in many designs has enabled change of speed gearing to be dispensed with, since in engines working under the compound system, arrangements are made to use high-pressure steam in both cylinders in order to surmount a hill or to transport a heavy load over a piece of bad road. Hence it is that water-tube boilers of various types have been found particularly suitable, while as far as the author is aware one type of fire-tube boiler is used for motor wagons.

Water-tube Boilers.—One of the most successful water-tube boilers is that of the Thornycroft Steam Wagon Company, Chiswick. This boiler is represented in section in Fig. 45, Plate 36, and really consists of two separate annular portions A and B, almost rectangular in section, connected by a number of cylindrical straight water-tubes which form the walls of a slightly tapered hollow cone C C. The furnace D is contained in the hollow of the lower annulus B, being fed through the opening in the upper annulus A, through the cover E, which can be removed for the purpose. The flame has to find its way on all sides through the narrow spaces left between the water-tubes, the products of combustion escaping by means of the funnel F. Particulars of evaporation of this and other boilers are given in Table 1 at the end of the Paper (pages 228, 229). The boiler next illustrated, as shown in half sectional elevation, Fig. 46, is in some respects similar to the Thornycroft, Fig. 45. The products of combustion, however, in this case escape entirely round the upper portion, thereby adding a feature of economy to this type of boiler, for perfectly dry steam is increased by the steam-dome H being contained in the smoke-box. The heating is effected by means of a petroleum burner J, the supply of which can be regulated by means of the screw-valve at K. Messrs. Merryweather and Co. have a boiler specially suitable for motor vehicles represented in Fig. 47. The feature of this boiler is the large size of fire-box L, which is entirely surrounded by the water space. The flames pass upwards encountering a double set of water-tubes, one being straight and slightly inclined from the horizontal, and the other being curved and vertical, and from their position insuring a very complete circulation of the water above the furnace. The De Dion boiler shown in Fig. 48, is better known in France than in this country, but at the Liverpool trials on the Bayley wagon it proved itself a very efficient steam generator. It consists, like the Thornycroft, of a double annulus of rectangular section, connected by water-tubes, the essential difference between these two boilers being that one annulus M is much smaller than the other, being partly contained in it and the water-tubes connected with them, instead of being vertical as in the Thornycroft, are slightly inclined from the horizontal. The furnace N, as in the case of the Thornycroft, is fed through a cover P. It is obvious that the heating-surface is disposed to the best advantage, as the results given on pages 228–229 show.

Flash Boilers.—This type of boiler in which a small quantity of water is injected at each stroke of the engine into a heated coil of metal to be flashed into steam and superheated, is by no means new. More than twenty years ago a small engine of this type, the invention of Mr. Henry Davey of Leeds, was working in the engineering laboratories of University College, London, and gave about ¾ H.P. Professor Kennedy, who showed it to the author, at that time expressed a favourable opinion of its future possibilities, but it cannot be said that this type of boiler has really come much to the front until it was revived by Serpollet a few years ago in connection with motor vehicles. The boiler of M. Serpollet has undergone a considerable modification during the past year. It originally consisted of a battery of thick steel tubes, jointed together by bends outside the furnace, the thick steel tubes which were originally circular being squeezed together, and finally indented so as to give a kidney-shape section, the concave side being towards the flame, and a very narrow space left for the water to pass through. M. Serpollet has now modified his boiler so that it consists of two portions, the lower being thick steel tubes twisted into a helical form, and placed so as to intercept the flame as much as possible, as shown in plan and elevation A A, Fig. 49, Plate 37. The upper portion consists of a coil B, of cylindrical tube of lighter section and not twisted as in the lower portion which is exposed more directly to the flame. The heating, which was originally effected by coke or coal furnace, is now done by means of a petroleum burner. Messrs. Simpson and Bodman have a very strong and effective flash boiler, which is shown in sectional elevation and side elevation in Fig. 50. This boiler consists of a series of heavy steel tubes C, indented after the Row condenser pattern and connected outside the furnace by a Haythorn joint E E, which is shown in section. The Row indentations alternate about 168 times in the generator, and any fluid passing round them must encounter an amount of baffling that would expose it in the most effective way to the action of the heating surface. The steam is made to pass through a drum D, which is found necessary to prevent the superheated steam having too high a temperature. The boiler is heated by a coal furnace F F, and, in about 40 minutes from lighting the fire, steam is generated. There are many boilers of course in which steam can be generated more quickly, but it must be remembered that the success of this type of boiler depends upon a reasonable mass of metal in which heat can be stored. Tangye's boiler, Fig. 51, is convenient and compact in form, and consists of a single coil of steel tube in conical form, the lower part of which is shown in plan. One of the newest forms of combined boiler and burner is that of Messrs. C. and A. Musker of Liverpool, Fig. 52. This is placed in a horizontal position underneath the vehicle, requiring no chimney for the escape of the waste products of combustion. It consists of three cylindrical coils H H of strong steel tubes, and the flame is made to circulate in the annular space between them. The point at which the water enters is shown on the drawing, and likewise that at which the steam is supplied to the engine. In a test made by the author on one of these boilers it was found that in a period of 40½ minutes, 37½ gallons of water were evaporated, the steam-gauge remaining during this period almost absolutely steady at 300 lbs. per square inch. To evaporate this quantity of water, 3½ gallons of commercial petroleum was used. As the weight of this boiler and contents, including the burner, was only 4 cwt. this represents roughly 15 lbs. per H.P., and indicates the great steaming capacity of this type of boiler and its suitability for motor vehicles.

Electricity.

The whole problem of the use of electricity is determined by the life and capacity of the battery, and the merits of any accumulator should really be judged to a great extent by the condition of its batteries after six months' daily use in a motor vehicle. The fact is that the sudden heavy discharges, so often taking place with a motor vehicle, expand the grids and release paste, which is washed out by the movement of the surrounding acid, and these detached particles cause internal short-circuiting by remaining in suspension between the plates. If a cell is short of "acid room," excessive heating expands the grids to such an extent that they never contract sufficiently to make good their connection with the remaining paste. Moreover splashes of acid are the cause of much more loss than is usually suspected. Again, the practice of grouping cells in parallel is open to the serious objection that if a cell on one side becomes dead or is reversed, those on the other expend energy in re-establishing equilibrium. English, French, and American tests prove that after six months' running, even under the most careful supervision, practically all secondary cells must have the positive plates re-pasted or renewed at a cost not below one-fifth of the original outlay, while in many cases as commonly used they are practically worthless at the end of this period or even sooner. So long as a range of 40 miles per charge, at speeds not exceeding 10 miles per hour, meets the requirements of an automobilist, electricity, at a cost of not more than 2*d.* per B.T.U., is at least on a par with steam or oil even for heavy traffic. Where these limits are exceeded, electricity is inadmissible. Distances greater than 40 miles, and speeds greater than 10 miles an hour, involve prohibitive dead-weight and excessive discharge rates.

It is a pity that no electrical motor vehicles for heavy traffic have yet been brought to the practical stage, as this is to be regretted for several reasons. The ease with which each of the four wheels of a lorry can be driven is of particular importance in respect of available propulsive effort, whilst the motors and batteries can readily be disposed so as to leave the entire platform free for merchandise. The weight of accumulators is not included in the legal tare of three tons, and the slower rates of speed demanded in this class of traffic should permit of a low ratio of battery weight to total moving weight. Experience has shown that, with a total moving weight of one ton, one-third each being batteries, vehicle and load, the effective distance is about 48 miles at a speed of 8 miles per hour, and only about 24 miles at a speed of 15 miles per hour on average roads.

It must be borne in mind that the cells deteriorate sadly when used for high speeds; nevertheless, results have been attained on a motor vehicle by electricity which surpasses anything by any other kind of motive power. An account of these results has been given by the Marquis de Chasseloup-Laubat in the "North American Review" for September 1899, from which it is interesting to note that on 27th January 1899, Jenatzy, mounting a carriage not specially constructed for great speed, left the starting point (a straight, level road near Paris) and covered $1\frac{1}{4}$ mile (2 kilometres) in 1 minute and $41\frac{4}{5}$ seconds; the first 3–5ths mile (1 kilometre) with a standing start in 57 seconds, that is, at the rate of 39·2 miles (63·166 kilometres) an hour, and the second kilometre with a running start in $44\frac{4}{5}$ seconds, that is, at the rate of 50 miles (80·357 kilometres) an hour. On 4th March 1899, Comte de Chasseloup-Laubat, on a Jantard carriage, not specially built for this style of test, but with certain most important modifications, such as running the front and rear of the carriage into sharp points, so as to offer least resistance to air, covered the same course of $1\frac{1}{4}$ mile (2 kilometres) in 1 minute $27\frac{2}{5}$ seconds, the first kilometre with a standing start in $48\frac{3}{5}$ seconds, or at the rate of $46\frac{1}{2}$ miles (75 kilometres) an hour, and the second kilometre with a running start in $38\frac{4}{5}$ seconds, or at the rate of $57\frac{3}{5}$ miles (92·783 kilometres) an hour. Finally, on 29th April 1899, Jenatzy, riding a carriage specially built to break all records, and which has the shape of a large cigar mounted on four small wheels, made $1\frac{1}{4}$ mile (2 kilometres) in 1 minute $21\frac{4}{5}$ seconds, the first kilometre with a standing start in $47\frac{4}{5}$ seconds, and the second kilometre with a running start in 34 seconds, or 65 3–5ths miles (105·852 kilometres) an hour. The extraordinary nature of these results lies not so much in the fact of a high speed of 65 miles an hour by a motor vehicle, but in the fact that starting from rest the average speed for the first kilometre was 46½ miles an hour. It is safe to say that no locomotive has ever achieved this result, that is, a distance of a mile covered from rest in less than 80 seconds, and those who witnessed the trials say that the start of the electrical carriages under these conditions left the same kind of impression on the observers as the start of a rocket. There is little doubt that these results could be beaten if the consequent expense were to be faced, but, according to report, the batteries were themselves practically destroyed in the run, and at any rate the contesting vehicles were not only towed out to the scene of the trial, but towed home again afterwards, and the trial, though interesting as showing the possibilities and use of electricity, must not at all be taken as giving results which could be of use for practical purposes.

Gearing or Transmission.

The ordinary modes of transmitting power, viz., by friction gearing, toothed-wheels, belts and chains, have been specially adapted and employed for transmitting the power from the motor to the driving wheels of a motor vehicle. The requirements for this particular purpose are in many respects of a special character, and the author had collected material for a special section of the Paper devoted to this subject. It has become evident, however, that it would be impossible to treat the question in a satisfactory manner within the limits of this Paper, and the subject well deserves a special Paper before the Institution. Take for instance the transmission of power by chain-gearing. This mode of transmission, from being in a very crude state a few years ago, has received so much attention that chain-gearing is as efficient, if not more so, than any other mode of transmitting power ; whereas the wearing of the links of the chain, which as it occurs gives so much trouble and annoyance, has been met by the special provision of large bearing surfaces which are hardened, so that the mechanism of the chain-gear may be said now to compare favourably with the other working parts of the engine, such as cross-head pins and main bearings. The efficient lubrication of the chain is a matter of the greatest importance and difficulty. The grease chiefly requires to be *inside* the joints, and Major R. E. Crompton showed the author a most ingenious way of effecting this which he has most successfully employed with bicycle chains. He places the chain in a bath of melted grease, in which graphite is mixed. The air being expelled from the joints of the chain by the heat, the mixture naturally finds its way between the pins and rollers, and forms a complete internal solid lubricant, when the whole is allowed to cool together.

The Renold chain, which is largely used in heavy motor traffic, is a beautiful invention which meets in a most ingenious manner the change of alteration of pitch due to wear, and the latest improvements in this chain are also designed to obviate as far as possible the wear upon the pin itself, and reduce it to a minimum.

Again, one special feature of the oil-engine is the necessity for change of speed-gearing of some form or other, and this has led to a large number of arrangements of speed-gearing which of themselves are worthy of detailed consideration. Besides the arrangements for changing the speed-ratio by means of combination of toothed-wheels are inventions such as the expanding and contracting pulley of Mr. Lucas, the arrangement for altering the throw of an eccentric through which the power is transmitted such as in the invention of Mr. Newton, and last, but not least, the most ingenious hydraulic variable speed-gear of Mr. Hall. These inventions are all in actual operation with apparent success, but unless actually examined they could not really be understood, except by means of drawings with detailed descriptions. It is obvious therefore that this part of the subject must be left for future treatment.

IV. RESULTS AND CONCLUSIONS.

In considering the actual results which have been obtained by motor vehicles, we must make a distinction between pleasure vehicles and those for the conveyance of goods. For the former, the actual cost of working is not by any means the first consideration; in a large number of cases in fact the cost is comparatively of small importance. Questions of comfort, durability and safety, as well as freedom from liability to break down, are the chief points to be considered. These matters can scarcely be summed up except as the result of lengthy experience, and now undoubtedly that experience is gradually being acquired. Before this Paper is read, the most important trial that has taken place in this country of pleasure vehicles will have begun, in the form of a 1,000 miles tour, undertaken under the auspices of the Automobile Club. More than eighty vehicles have entered in this competition, which is to take place over a large part of England and Scotland. These vehicles, which will run over all kinds of roads, and in all weathers, will be all under the same conditions, and the careful observations and records which will be taken of their behaviour will doubtless give the most valuable opportunity which has yet been afforded for intending purchasers to form an opinion of their relative merits.

When we come to the question of goods traffic, the matter is of course entirely one of cost, including not merely the outlay, working, and upkeep, but deterioration, which in road vehicles is exceptionally heavy. Extended trials of actual working are necessary for any final opinion of the relative merits of different types of heavy motor vehicles, and the author has fortunately been able to secure much valuable testimony of this sort on the subject (*see* Appendices).

A great deal, however, can be ascertained by careful trials such as those which have been undertaken on two occasions at Liverpool (1898 and 1899), since measurements and data can be obtained with a staff of observers for a limited period, which could scarcely be secured in continuous working. The results of these trials have been given in the reports upon them, which, for the purpose of this Paper, have been summarised and thrown into an entirely new form in Table 1 (pages 228–229), a study of which will enable an opinion to be formed on many points of interest.

Take, for instance, the fuel consumption of the Thornycroft vehicle on the two successive trials, and it will be noticed under the heading "Fuel," the consumption fell from 3·64 lbs. of Welsh coal per net ton-mile of freight to 2·38 lbs. of Welsh coal in the following year. Again, take the improvement in the design of the same vehicle as shown by the ratio of dead mean weight to freight, which fell from 1·29 in 1898 to 0·96 in 1899. In the same way the performance of the various heavy motor vehicles can be compared by studying this Table, since the results were all obtained under exactly similar conditions of road and weather, and over exactly the same course of nearly 40 miles. The figures form a series of facts the truth of which cannot be disputed, and of the practical value of which engineers will doubtless be able to form their own opinion.

Table 2 (page 230) is an attempt to give the various items of expense for two motor vehicles, one carrying four tons and the other eight tons, the data being arrived at from a consideration of all the best types of motor vehicles at present in operation. This Table cannot of course pretend to absolute accuracy, and many of the items will vary considerably in different localities; but anyone can alter for himself any of the details, such as the wages or repairs, and make the necessary corrections in order to form some conclusions of a practical nature. These results have been used in arriving at the motor curve, Fig. 53 (page 224).

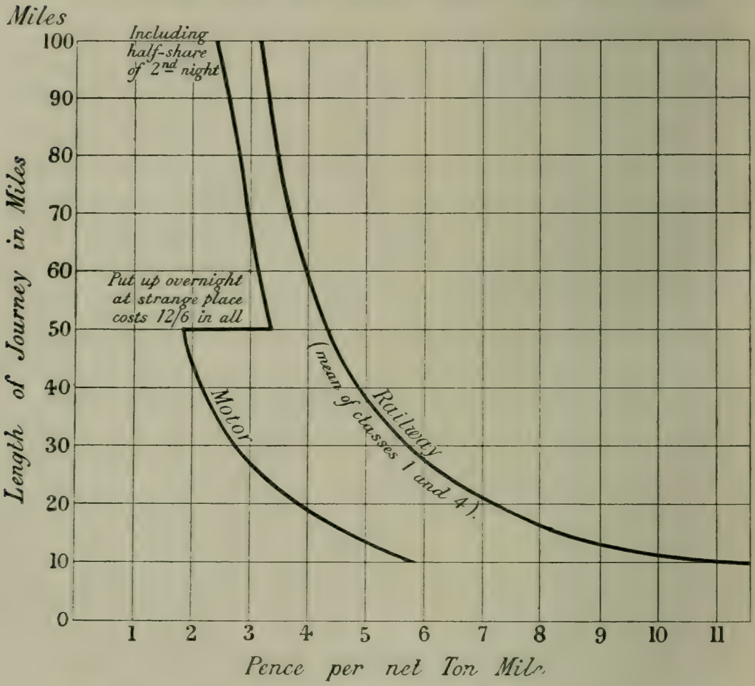
Estimated Cost of Transport by a Motor Wagon carrying Four Tons of Freight.

Miles	20	25	30	35	40	45	50
Pence	3·90	3·21	2·76	2·43	2·18	1·99	1·84

In the data for obtaining the results for the above Table £75 per annum has been taken as the minimum amount for repairs, with an increment of £7·5 for each 5 miles above 20 per diem. It has been assumed that the boiler is under fire for 70 hours per week, at a minimum fuel consumption averaging 30 lbs. of gas-coke per hour, with an increment of 2·5 lbs. per hour for each 5 miles above 20 per diem. Saturdays are regarded as half-days, and only 50 working weeks are reckoned per annum. If a single-trailer carrying another 4 tons of freight be added, the costs per net ton-mile are practically reduced by one-half; if only half the net ton-mileage is obtained, that is, equivalent to 2 tons of freight throughout, the costs per net ton-mile are practically doubled.

The next way of estimating the cost is naturally to try and arrive at some comparison of the cost of the motor wagon with that of the railway.

Fig. 53. Relation between cost of transit by Railway and by Motor Vehicle.



The following are the general figures which have been abstracted from the Blue Book of 1892,* and from this the railway curve, Fig. 53, has been plotted, and this must be considered in connection with the motor curve on the same figure.

Now it must be remembered that, in considering this comparison, the costs per net ton-mile are assumed to take the place of

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* Analysis of the Railway Rates and Charges Order Confirmation Acts, 1891 and 1892.

Comparison between Railways and Motors.

Miles	10	20	30	40	50
Railway (Pence per net ton-mile)	11·54	7·18	5·62	4·84	4·37
Motor (Pence per net ton-mile)	5·90	3·90	2·76	2·18	1·84

railway charges added to cartages, and not to include the receiving and delivering at distances common to both. This point must be borne in mind, as a failure to appreciate it has led to more than one occasion of misunderstanding of the advantages of the motor vehicle, which it undoubtedly has over short distances. In one direction there certainly does appear a field for profitable construction, namely, to make the motive portion detachable from the main body of the lorry or wagon, and capable of transporting itself for purposes of moving a similar wagon or lorry, which is waiting elsewhere. This would meet one of the greatest objections to motor vehicles which occurs in the detention of the expensive part of the vehicle (namely, the motor and gearing) for long periods, during which the lorry is waiting to either receive or discharge its load. This is analogous to the cause which has led certain shipowners to abandon steam-barges in favour of the use of steam-tugs. Something in this direction is apparently urgently needed in connection with motor traffic.

Whatever value may be attached to the statistics of trials, the independent experience of those actually using motor wagons must have even greater weight. The author has been fortunate in securing from Mr. A. G. Lyster, the docks engineer of Liverpool, and Mr. John A. Brodie, the city engineer of Liverpool, and Mr. H. A. Hoy, the chief mechanical engineer of the Lancashire and Yorkshire Railway, statements concerning the use of the motor vehicles which they have now for some time had in operation. These will be found in the form of Appendices, as it is far better that the statements of gentlemen so well able to express a sound and at the same time impartial opinion should be given in their own words. The two former have Leyland wagons, and the latter a Thornycroft wagon, and it will suffice to remark here that their testimony is unanimous in favour of these vehicles as compared with horse-traction. The value of such testimony lies in the fact that these motor wagons are in each case not really employed to do a new class of work, but to take the place of a certain number of ordinary wagons.

There is thus every reason to believe that the heavy motor vehicle, at any rate, has before it a very important future, and it is gratifying to think that English engineers are well to the front in the design and manufacture of such vehicles. For instance, the details (taken from the report of the French trials) of one of the best of the French heavy motor vehicles is given in Table 1 (page 228), namely the De Dion, and the point specially to be noted is the very great tare weight of this vehicle, which exceeds so largely any of those of English design and manufacture. This is no doubt to a great extent owing, not to any superior virtue on the part of English makers, but to the legislative restrictions of the Highways Act in this country, which compel a maximum tare weight of 3 tons. The fact remains however that this limit is too low in view of the loads which are now expected to be transported on wagons, 8 tons (and frequently 10 tons) being a common load on Liverpool lorries. Representations have been already made to the Local Government Board on this subject, which it is hoped will bear some fruit in at any rate a moderate relaxation of this tare limit, since it is found extremely difficult to obtain the necessary strength and durability with the lightness of structure required by the 3-ton limit, even with the aid of such an expensive metal as aluminium.

Whilst the special improvements and inventions of the various makers engaged are properly and legitimately protected by patents, all the essential features of the motor vehicle are absolutely free from restrictions as to manufacture and sale, nor has there been any attempt at company promoting on a large scale with this class of vehicles. In this the history of the recent development of the subject bears a remarkable contrast to that of lighter motor vehicles for pleasure purposes. The position of affairs in regard to the latter has been brought forward in a remarkable Paper * by the Hon. John Scott Montagu, M.P., on "The General Aspects of British Automobile Manufacture." In this Paper, a thorough exposure of the iniquitous system by which the general public is defrauded by company promoters has been made in a most courageous and emphatic manner. Contrary to general belief the engineering profession suffers much by such practices. When there is a prospect of the healthy development of any engineering enterprise which has been gradually and carefully led up to by the successive efforts of many inventors, who have probably obtained nothing but loss and disappointment from their labours, an invention, more or less successful, which can be boomed, is made use of by the company promoter in such a way as to cause a promising industry to be looked upon for many years with suspicion and distrust by the general public. It is however satisfactory to know that the light motor car, including the oil engine, is as free to all engineers to develop as the corresponding branch of the heavy motor industry.

Looking at the whole question, it may be safely said that the motor vehicle has come to stay, and that its uses both in peace and war will rapidly and enormously develop. The public interest, which is now seen partly by the enormous number of patents taken out in connection with the industry, partly by the great growth of literature on the subject, and by the formation of automotor clubs, is not a mere transient thing, and although the motor vehicle is at present still somewhat of a *rara avis* upon our roads, it may not be going too far to think that the coming century will see a development of locomotion upon roads comparable with the development of locomotion of the railway in the century which according to our individual views of chronology is either past or so very nearly past.

In concluding this Paper the author desires to acknowledge the services of Mr. Bibby, B.Sc., who has drawn nearly all the Figures, which are in many cases entirely new.

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* Automotor Journal, February 1900.

TABLE 1.—*Liverpool Trials of Motor Vehicles for heavy traffic*—(*continued on next page*).

Results of the years 1898 and 1899 compared.

Year.	Vehicle.	Tare.	Freight.	Mean total moving Weight.	Ratio of mean Dead Weight to Freight.	Proportion of mean total moving Weight on Driving-Wheels.	Boiler.	
							Average of observed Pressures.	Heating Surface.
		Tons.	Tons.	Tons.			Lbs. per sq. inch.	Square feet.
1898	Thornycroft (4-wheeler)	2·83	2·53	5·91	1·29	0·77	152	65
1899	Do. do.	3·00	3·73	7·24	0·96	0·68	147	83
1898	Thornycroft (6-wheeler)	3·85	4·73	9·25	0·93	0·46	125	65
1899	Do. (8-wheeler)	3·90	6·65	11·28	0·71	0·54	176	83
1898	Leyland	2·86	4·06	7·29	0·78	—	178	110
1899	Do.	2·85	4·44	7·64	0·71	0·62	167	110
1898	Lifu	2·39	2·20	4·94	1·21	0·77	207	80
1899	Clarkson	3·00	3·35	6·68	1·00	0·51	193	80
1898	De Dion (French Trials)	4·72	3·25	8·60	1·65	0·60	?	56
1899	Bayley	2·97	3·67	7·13	0·95	0·67	174	70

TABLE 1—(*concluded from opposite page*).

Year.	Vehicle.	Engine.		Ratios of gearing between Engine-Shaft and Driving-Wheels.	Consumption per net ton-mile of freight.		Speed. Miles per hour.		Prime cost.
		Compound Cylinders.	Revs. per min. at full speed.		Fuel.	Water.	Actual running.	Commercial.	
1898	Thornycroft (4-wheeler)	Inches. 4 and 7 × 5	500	8 to 1	Lbs. Welsh Coal. 3·64	Gals. *1·46	5·98	5·22	£ 630
1899	Do. do.	do.	770	10·1 and 17·7	2·38	1·88	5·94	5·31	590
1898	Thornycroft (6-wheeler)	4 and 7 × 5	500	9 and 12	4·03	*1·93	3·41	2·79	750
1899	Do. (8-wheeler)	do.	770	10·1 and 17·7	1·87	1·33	6·48	5·67	640
1898	Leyland	3 and 5 × 6	500	8, 13·5 and 28	Gals. Kerosene. 0·130	*0·84	5·25	4·45	375
1899	Do.	2¾ and 5 × 6	400	8·5, 15·25 and 35	0·121	*0·91	6·17	5·02	450
1898	Lifu	3 and 6 × 5	600	8 to 1	0·298	2·06	8·29	7·02	525
1899	Clarkson	2¾ and 6 × 4	600	12 and 36	0·216	†0·64	5·59	4·94	450
1898	De Dion (French Trials)	4 and 7¾ × 6	600	7·4 and 12·5	Lbs. Gas Coke. 1·81	1·68	6·33	5·47	760
1899	Bayley	4 and 7 × 5	500	8·4 and 13·7	1·84	1·27	5·54	4·93	600

* Surface Condenser. † Wired Tube-Condenser and Fan.

TABLE 2.—*Estimated Annual Expenditure.*

Class of Work.	Weight of Freight carried.	
Per Week { 70 hours under steam, 220 miles fully laden. 50 weeks per annum.	4 tons on self-contained wagon.	8 tons on motor-wagon and trailer.
PRIME COST	£500	£600
Interest at 5 per cent. per annum .	25·0	30·0
Depreciation at 15 per cent. „ „ . .	75·0	90·0
Fuel—Gas Coke at 16*s*. per ton . . .	50·0	75·0
Water	3·0	4·0
Wages	91·0	110·5
Repairs (labour and materials) . . .	105·0	125·0
Oil, grease, and waste	10·0	12·0
Insurances	10·0	12·0
Rent, rates, and taxes	5·0	7·0
Total per annum, exclusive of establishment charges	£374·0	£465·5
Vehicle-miles per annum	11,000	11,000
Cost per vehicle-mile . . . . . pence	8·16	10·15
Net ton-miles per annum	44,000	88,000
Cost per net ton-mile . . . . pence	2·04	1·27
Cost, using liquid fuel—kerosene at 4*d*. per gallon, being three times as costly as coke at 16*s*. per ton.	*d.* 2·59	*d.* 1·68

APPENDIX I.

Statement by Mr. John A. Brodie, the City Engineer of Liverpool, on the working of a Leyland Motor Wagon.

After the trials of Motor Vehicles held by the Self-Propelled Traffic Association in May 1898, the Health Committee of the Corporation of Liverpool decided to obtain a motor wagon, and ultimately ordered from the Lancashire Steam Motor Co., of Leyland, Lancashire, one similar in design to the vehicle which had been awarded the first prize of one hundred pounds offered by the Society.

The vehicle was delivered at the end of January 1899, and has since been used in connection with the construction of street works for the Electric Tramways, where it has been found very useful for the quick removal of materials. On account of the varying character of the work, much of it being over very short distances, it has not been found possible to keep very accurate records of the weights of materials conveyed and the distances travelled, but, generally speaking, the load has been from 2½ to 4 tons, and the total daily mileage from 18 to 24, and even 30 miles occasionally.

Where the work has been of a regular character the records show that good work has been done; thus, in the week commencing 6th March the motors carried :—

March 6th . .	3 loads of	4 tons each,	3 miles loaded,	3 miles light.
7th . .	3 ,, ,,	4 ,, ,,	3 ,, ,,	3 ,, ,,
8th . .	4 ,, ,,	4 ,, ,,	3 ,, ,,	3 ,, ,,
9th . .	4 ,, ,,	4 ,, ,,	3 ,, ,,	3 ,, ,,
10th . .	2 ,, ,,	4 ,, ,,	3 ,, ,,	3 ,, ,,
11th . .	2 ,, ,,	4 ,, ,,	3 ,, ,,	3 ,, ,,

This shows that during the week a net ton-mileage of 216 was obtained, which at £7 per week gives a cost per ton-mile of 7¾*d.*

Again in October, over a somewhat longer distance, a week's work was as follows:—

October 23rd .	3	loads	of	2¼	tons	each,	4½	miles	loaded,	4½	miles	light.
24th .	3	,,	,,	3¼	,,	,,	4½	,,	,,	4½	,,	,,
25th .	3	,,	,,	3¼	,,	,,	4½	,,	,,	4½	,,	,,
26th .	2	,,	,,	3¼	,,	,,	4½	,,	,,	4½	,,	,,
27th .	2	,,	,,	3¼	,,	,,	4½	,,	,,	4½	,,	,,
28th .	1	,,	,,	3¼	,,	,,	4½	,,	,,	4½	,,	,,

This gives a net ton-mileage of 189, which at £7 works out to 8¾*d.*

In a trial made for the purpose of comparing the motor with hired horse-teams on day-work, on a haulage length of 3 miles, the results were as follows:—

Motor ..	4	loads	of	4	tons	each,	3	miles	light,	3	miles	loaded.
Teams (each)	3	,,	,,	2	,,	,,	3	,,	,,	3	,,	,,

This gives for motor 48 net ton-miles @ £1 5*s.* = 6¼*d.* per ton-mile.
,, ,, for teams 18 ,, ,, ,, @ £0 10*s.* = 10*d.* ,, ,, ,,

It should, however, be pointed out that where the haulage distance is smaller than 3 miles, the benefit obtained from the greater speed of the motor vehicle is much reduced, and it appears probable that on distances less than 1 mile the balance in favour of the motor vehicle would disappear.

In connection with the use of this motor vehicle in Liverpool, it has been found that the main frames of the vehicle were originally of too light a section to withstand the strains thrown upon them when travelling at a high speed when fully loaded. Many days have been lost owing to lengthened delays in replacing the main frames, and there has also been a further loss of time due to the wheels requiring important repairs. Since these repairs have been executed, the motor has given little trouble, and, taken on the whole, the results have been very satisfactory. The cost for twelve months' working, including wages, maintenance, repairs and £1 per week for depreciation, amount to £243 14*s.* 8*d.*

APPENDIX II.

Statement by Mr. H. A. Hoy, the Chief Mechanical Engineer of the Lancashire and Yorkshire Railway, on the working of a Thornycroft Motor Wagon.

The Lancashire and Yorkshire Railway Company has had a steam-lorry made by the Thornycroft Steam Wagon Company working since 4th December 1899. The lorry was used for town delivery from the company's Salford's depôt, near Manchester, until 10th February, when it was transferred to the same class of work at Great Howard Street Station, Liverpool, where it is still working. The car has run satisfactorily, and has been found to be about equal to two one-horse lorries. As, however, it has been used on all classes of traffic to ascertain its suitability, the results obtained vary somewhat. It has been found particularly useful in taking loads of about 3 tons on journeys where, owing to stiff gradients over a portion of the road, two horses would have ordinarily had to be sent. Whilst in Liverpool it facilitates delivery in allowing of a direct route being taken over gradients which a horse-drawn lorry could only surmount by taking a circuitous route.

Up to and including 31st March the car had run on 94 days, covering a total distance of 1,033 miles, or 10·99 miles per day, not including the distance travelled in collecting loads in the goods yards. In these calculations Saturday has been counted as a full day, although the car has not usually on that day worked after 2.0 p.m. The total load carried has been 670·14 tons in 289 loads, giving 3·07 journeys, with an average load of 2·318 tons per day. During the 94 days the car has been in steam 1,021·5 hours, or 10·86 hours per day.

Careful records have been taken of the coke and water used, and it has been found that 259·7 lbs. of the former and 191·7 gallons of the latter are the average daily consumption, giving an evaporation of 7·38 lbs. of water per lb. of coke. This latter is obtained from the company's gasworks at Horwich, being made from Wigan coal.

TABLE 3.—*One week's run of a Thornycroft Steam Lorry, employed by the Lancashire and Yorkshire Railway Co.*

Date.	Distance travelled.	Total load carried.	Loads.	Hours in steam.	Coke used.	Coke per mile.	Coke per hour.	Water used.	Water per mile.	Water per hour.	Water evaporated per lb. of coke.
1900.	Miles.	Tons.	No.		Lbs.	Lbs.	Lbs.	Gals.	Gals.	Gals.	Lbs.
26 February . . .	15	10·16	4	13	290	19·33	22·3	248	16·53	19·07	8·56
27 „ . . .	17	7·59	3	13	280	16·41	21·53	249	14·64	19·15	8·9
28 „ . . .	14	11·63	4	12·5	300	21·42	24·0	190	13·57	15·2	6·33
1 March . . .	15	11·53	4	12·5	320	21·33	25·6	269	17·93	21·52	8·42
2 „ . . .	14	9·15	3	12·5	270	19·28	21·6	184	13·14	21·6	6·82
3 „ . . .	12	3·95	2	9·5	210	17·5	22·1	156	13·0	22·1	7·44

It is found necessary to clinker the fire after about seven hours' running, the operation taking about five minutes. The coke consumed has been 23·4 lbs. per hour, or 22·05 lbs. per mile, whilst the water evaporated has been 17·14 gallons per hour, or 16·15 gallons per mile. The figures have been calculated from the days on which records were taken of both the water and fuel consumption.

The results, day by day, of a week's run in Liverpool are given in Table 3; these will be noticed to be slightly higher than the averages given. This is due to the fact that on the first few days, both at Liverpool and Manchester, the results were not good, owing to the driver not being accustomed to the yards and the methods of working.

APPENDIX III.

Statement by Mr. A. G. Lyster, the Engineer-in-Chief, Mersey Docks and Harbour Board, on the working of a Leyland Motor Wagon.

This machine, which is a motor wagon designed to carry a paying load of 4 tons, has its engine worked by steam generated by liquid fuel. The service is of a very special character, consisting as it does in conveying materials from a central dockyard, where they are manufactured, to the various parts of the estate where they are required for the works, comprising only comparatively short journeys, and returning with such loads as may be picked up for the yard or intermediate positions. The wagon is by no means, therefore, either constantly fully loaded or employed; it has to wait for longer or shorter periods, according to circumstances at its several stages or points for discharging or loading, or elsewhere; and altogether the conditions are extremely unfavourable for affording data which would be of benefit to firms whose work is of a more regular and uniform character.

The cost per ton-mile varies very largely according to the nature of the work, being as low as 3·4*d.* per ton-mile for the work done on a certain day, and at times very much higher, the average over the whole of the time worked giving a little over 9*d.* per ton-mile.

During the period to which this applies, viz., from the beginning of January to the middle of March, 1900, and providing a total of fifty-two working days, the actual working time was only 44 per cent. of the total.

The work for which the motor wagon was obtained had previously been done by horses and carts, and no exact data are available for comparison with the new vehicle. In general terms, however, the cost for the work done has been much less than it would have been by horses, and, as regards despatch and convenience, which are often of greater importance in urgent work than direct cost of transport, the comparison is immensely in favour of the motor vehicle.

It has been very efficient for the purpose for which it was obtained, and its working has been entirely satisfactory. No difficulty whatever has been experienced in manœuvring, but on one or two occasions, after a heavy snowfall, some difficulty was found in starting. This, however, was soon overcome.

APPENDIX IV.

Statement of work done by Messrs. Fuller and Co.'s Steam-Dray. Built by the Thornycroft Steam Wagon Co.

The Fuller steam-dray commenced in regular service on 9th January 1899; the motor-dray is constructed to carry 3 tons, and the trailer bears a further 2 tons; the legal limit of running speed is 5 miles per hour. The vehicle has proved fully equal to the work for which it was designed, and has on several occasions carried a useful load of nearly 6 tons out, and 2 or 3 tons home, on a total day's run of 38 miles. In the matter of speed also the dray is very satisfactory, an average speed of about 6 miles an hour having been maintained over long runs, with load. An analysis of the performance of this vehicle during the past fifteen months, gives the following results:—

Average total mileage per working day	33
Working days per annum	260
Net ton-miles per annum	25,000

The total cost per net ton-mile, inclusive of interest, depreciation, wages, fuel, adjustments and repairs, and stores, is 3·4 pence. Taking the usual allowance of five barrels (each 36 gals.) per ton, it appears, therefore, that the cost of transport per barrel-mile is 0·68 penny. Messrs. Fuller and Co. find that the vehicle easily does the work of three of their two-horse drays.

APPENDIX V.

Statement by Mr. Bryan Donkin, Member of Council, on the Tests of Motor Carriages at Richmond and Birmingham.

Table 4 (pages 240–245) gives 26 English tests on carriages and lorries, made in the summer of 1898–99 by the Judges of the Automobile Club and the Royal Agricultural Society, chiefly on oil motors, many of foreign origin. The first eighteen tests were on oil-engines, driving passenger carriages of various weights, at Richmond. The run was from Southall, near London, along the Oxford road and back. The same oil spirit was used in all the oil-tests. The maximum speed allowed on the roads was 12 miles per hour, although in some cases it was exceeded. The roads were dry and in good order, but there were many hills; a section of the route is given in the original Report. Each carriage was tested separately for hill-climbing capacity on the Petersham Hill, Richmond, which has a maximum gradient of 1 in 9½.

A trained official attendant was in each carriage during the whole test. He noted all incidents, with causes and duration of stoppages, if any, and was also responsible for the measurement of the oil used, &c. The I.H.P. was not determined, as with these small motors it is very difficult to measure it; when running on roads it varies much. The question is therefore how to obtain a comparative figure of merit as to quantity of oil used, and thus to compare these numerous carriages and lorries, of very various weights, sizes, types, speeds on roads, speeds of motors, difference of gearing, with one or more cylinders of various diameters and strokes. In this Table they are classed in order of merit of the cost in pence of the oil spirit per ton-mile run, of total running weight. This was also done for the Birmingham tests of the Royal Agricultural Society by Professor Unwin, and seems an excellent standard to adopt. This cost per ton-mile, which takes count of weight, speed, and price of oil or fuel, will be found in Column 14. The total weights varied from 1·6 ton to 0·163 ton. All these little motors run nominally at from 400 to 1,400 revolutions per minute, but on the road this varied much. The cost of the oil spirit per ton per mile varied from one farthing to one penny farthing, the same being used throughout. The most economical vehicle, ran at only one-sixth the cost of the least economical. This ratio of difference is very great, and the causes should be ascertained.

Tests 19 to 21 give three trials for heavy vehicles for carrying loads, made at Richmond by the Automobile Club, for a 20-mile run, the same oil spirit being used as before. Total running weight from 8·6 to 2·1 tons. Speed on road 4 to 6 miles an hour. The cost of the spirit varied from about one to three-farthings per ton per mile. Column 16 gives the kind of reducing gear from the motor crank shaft to that of the carriage wheels.

The next two tests, 22 and 23, were on steam lorries for carrying goods, also made at Richmond during a 20-mile run. Each had a steam boiler and compound engine, and used coal or coke; one weighed 6·6 tons, and the other 6·9 tons, and ran well at a speed of from 5¼ to 5½ miles per hour. The cost of the fuel per ton per mile works out very low.

Tests 24 to 26 show three trials at Birmingham by the Judges of the Royal Agricultural Society, made in 1898 on lorries for goods during a run of nearly 47 miles. One was an oil, and the other two steam motor-cars. The weights varied from 2½ to 6⅞ tons. Speed on road 6¼ to nearly 8 miles per hour. The cost per mile per ton is here also very low. These few steam tests form a useful comparison with the oil motors.

TABLE 4 (*continued on opposite page*).

18 *Tests of Oil Passenger-Carriages at Richmond in Summer of* 1899 *by Judges of the Automobile Club.*

50–mile run, Southall to High Wycombe. All using same Petroleum
English and foreign carriages, tabulated in order of
Maximum speed allowed 12 miles per hour.

Table prepared by Mr. BRYAN

No.	Makers' name of Oil carriage.	No. of passengers including driver.	Weight total running loaded.	Motor Cylinders.			Nom. revs. per min.	Changes of speed.	Ignition.*	Mean speed—miles per hour.
				No.	Diam.	Stroke.				
			Tons.		Inch.	Inch.		No.		
1	Société Parisienne .	4	1·140	4	2·75	4·25	1,200	2	E	10·5
2	Daimler Motor Co., London.	4	1·350	2	3·56	4·75	720	4	T	12·2
3	Delahaye.	4	1·260	2	4·33	6·30	750	3	E	12·0
4	Daimler Motor Co., London.	6	1·480	2	3·56	4·75	720	4	T	11·6
5	Motor Mnfg. Co.	5	1·420	2	3·50	4·75	720	4	T	12·0
6	Daimler Co., Germany .	4	1·380	2	3·44	4·56	720	4	T	11·2
7	Lanchester. .	3	0·850	2	5·00	4·50	500 to 1,000	2	E	12·1
8	Panhard & Lavasseur .	2	1·030	4	—	—	700 to 800	4	T	12·1
9	Benz . . .	4	1·100	2	4·75	5·00	500	3	E	12·3
10	Benz . . .	2	0·535	1	4·50	5·00	400	3	E	12·2
11	Daimler Motor Co., London .	2	0·625	2	3·00	4·75	750	2	T	11·1
1	2	3	4	5	6	7	8	9	10	11

* E = Electric ignition; T = Tube Ignition.

(*continued on next page*) TABLE 4.

18 *Tests of Oil Passenger-Carriages at Richmond in Summer of* 1899
by Judges of the Automobile Club.

spirit of 0·68 specific gravity; cost taken at 1*s.* per gallon.
merit of cost spirit per mile per ton gross weight.
Roads fair and dry.

Donkin, Member of Council.

Cost of Spirit.		Cost of Spirit per mile per ton.	Wheel tyres.*	Gear.	Remarks on Road and on Hill—50 miles run. All 4-wheel vehicles. Authority—Judges' Report 1899.	Official No.	No.
Per mile.	For 50 miles.						
Pence.	Pints. *s.* *d.*	Pence.					
0·30	10 = 1 3	0·265	Pn.	Strap	Not very good on road. Automobile Association	32	1
0·36	12 = 1 6	0·266	Pn.	Wheels and Chain	Very good on hill and road. 5½ H.P. nominal	18	2
0·36	12 = 1 6	0·285	Pn.	Strap	Good on road. 12 miles per hour assumed, but went faster.	26	3
0·54	18 = 2 3	0·365	S.R.	Wheels and Chain	Very good on road. Less good on hill. 5½ H.P. nominal.	19	4
0·60	20 = 2 6	0·421	S.R.	Do.	Good on road. Less good on hill. 12 miles per hour assumed. Went faster.	27	5
0·60	20 = 2 6	0·435	S.R.	Do.	Good on road. Hill not good. 4 H.P. nominal. Motor Supply Co.	16	6
0·42	14 = 1 9	0·495	Pn.	Worm wheels	Good on road and on hill.	24	7
0·54	18 = 2 3	0·523	Pn.	Wheels and Chain	Do.	29	8
0·54	18 = 2 3	0·533	S.R.	Belt and Chain	Very good on road and on hill. Hewetson.	21	9
0·30	10 = 1 3	0·561	S.R.	Do.	Good on road, not good on hill. Hewetson.	22	10
0·36	12 = 1 6	0·578	Pn.	Wheels and belt	Road very good. Hill good.	20	11
12	13	14	15	16	17	18	19

* Pn. = Pneumatic; S.R. = Solid Rubber.

TABLE 4 (*continued on opposite page*).

18 *Tests of Oil Passenger-Carriages at Richmond in Summer of* 1899 *by Judges of the Automobile Club.*

50–mile run, Southall to High Wycombe. All using same Petroleum
English and foreign carriages, tabulated in order of
Maximum speed allowed 12 miles per hour.

No.	Makers' name of Oil carriage.	No. of passengers including driver.	Weight total running loaded.	Motor Cylinders. No.	Motor Cylinders. Diam.	Motor Cylinders. Stroke.	Nom. revs. per min.	Changes of speed.	Ignition.*	Mean speed—miles per hour.
			Tons.		Inch.	Inch.		No.		
12	Du Croiset . .	6	1·600	2	4·50	8·00	650	3	E	13·9
13	Liège Works .	2	0·390	1	3·75	5·00	900	3	E	11·7
14	Marshall . . .	2	0·730	1	5·00	5·50	600	1	E	6·8
15	Bergmans . .	2	0·770	1	5·00	6·25	800	3	E	9·5
16	Barrière . .	1	0·163	1	2·75	3·00	1,400	1	E	11·0
17	Vallée . . .	2	0·650	2	3·25	5·25	610	3	E	11·7
18	International . Motor Car Co.	2	0·575	1	5·00	5·25	800	3	E	8·7

3 *Tests on Oil Motors—*1 *Post Office Van and* 2 *Lorries for goods.*

		Load in Tons.								
19	Daimler Motor Co., Germany.	5	8·650	2	4·31	6·12	540	3	T	3·8
20	Daimler Motor Co., London .	1½	3·950	4	3·56	4·75	800	4	T	5·0
21	Daimler Motor Co., Germany.	1½	2·140	2	3·81	5·37	660	4	T	5·8
1	2	3	4	5	6	7	8	9	10	11

* E = Electric ignition; T = Tube Ignition.

(*continued on next page*) TABLE 4.

18 *Tests of Oil Passenger-Carriages at Richmond in Summer of* 1899 *by Judges of the Automobile Club.*

spirit of 0·68 specific gravity; cost taken at 1*s.* per gallon.
merit of cost spirit per mile per ton gross weight.
Roads fair and dry.

Cost of Spirit.		Cost of Spirit per mile per ton.	Wheel tyres.*	Gear.	Remarks on Road and on Hill—50 miles run. All 4-wheel vehicles. Authority—Judges' Report 1899.	Official No.	No.
Per mile.	For 50 miles.						
Pence.	Pints. *s.* *d.*	Pence.					
1·02	34 = 4 3	**0·638**	S.R.	Belt and chain	Good on hill and road. Automobile Association.	34	12
0·39	13 = 1 7	**1·000**	Pn.	Wheels and belt	Good on road, not good on hill. Automobile Association.	36	13
0·76	25 = 3 1	**1·040**	Pn.	Do.	Not good on hill and road.	25	14
0·84	28 = 3 6	**1·100**	Pn.	Do.	Good on hill, but not on road. Automobile Association.	35	15
0·18	6 = 0 9	**1·110**	Pn.	Cogs	On hill good, on road fair. Automobile Association.	1	16
0·78	26 = 3 3	**1·200**	Pn.	Belts and chain	Good on hill and road. Automobile Association.	31	17
0·72	24 = 3 0	**1·260**	S.R.	Do.	Many stops on road. Hill fair.	23	18

Richmond 1899. *20-mile run. Spirit as above. Same Report.*

Pence.	Pints. *s.* *d.*	Pence.					
2·40	32 = 4 0	**0·280**	Iron	Wheels	On roads good. 10 H.P. nominal. Motor Carriage Supply (Lorry).	42	19
1·80	24 = 3 0	**0·450**	S.R.	Wheels and chain	Post Office covered van. Good on road.	44	20
1·60	22 = 2 9	**0·750**	Iron	Wheels	Lorry. Good on road. 6 H.P. nominal. Motor Carriage Co.	43	21
12	13	14	15	16	17	18	19

* Pn. = Pneumatic; S.R. = Solid Rubber.

TABLE 4 *(continued on opposite page).*

2 *Tests on* 2 *Road Steam Lorries with Boiler. For Goods. Richmond* 1899.

No.	Makers' name of Steam carriage.	Load in Tons.	Weight total running loaded.	Motor Cylinders.			Nom. revs. per min.	Changes of speed.	Ignition.	Mean speed—miles per hour.
				No.	Diam.	Stroke.				
			Tons.		Inch	Inch.		No.		
22	Bayley . . .	4	6·630	2	4·0 6·5	5·5	500	2	—	5·22
23	Thornycroft .	3	6·950	2	4·0 7·0	5·0	440	2	—	5·45

3 *Tests—*1 *Oil Motor and* 2 *Steam Lorries for Goods. Proceedings of the Royal*

No.	Makers' name of carriage.	Load in Tons.	Weight total running loaded.	Motor Cylinders.			Nom. revs. per min.	Changes of speed.	Ignition.	Mean speed—miles per hour.
				No.	Diam.	Stroke.				
			Tons.		Inch.	Inch.		No.		
24	Daimler Motor Co., London. (Oil spirit) .	1	2·49	2	3·62 3·62	6·37	700	4	—	7·82
25	Thornycroft (Steam) . .	3	6·88	2	4·00 7·00	5·00	500	0	—	6·20
26	Lancashire Co. (Steam) . .	3·1	6·54	2	3·00 5·00	6·00	500	3	—	6·48
1	2	3	4	5	6	7	8	9	10	11

(*concluded from page* 240) TABLE 4.

20-*mile run. Coal and coke. Compound Steam-Engine. Same Report.*

Cost of Fuel.		Cost of Fuel per mile per ton.	Wheel tyres.	Gear.	Remarks on Road and on Hill—50 miles run. All 4-wheel vehicles. Authority—Judges' Report 1899.	Official No.	No.
Per mile.	For 50 miles.						
Pence.	*s.* *d.*	Pence.					
Coke. 0·32	0 6½	Coke. 0·050	Steel	Gears	Good on road. Steamer. Coke fuel, 10*s.* per ton.	45	22
Coal. 1·05	1 9	Coal. 0·150	Do.	Do.	Good on road. Steamer. Coal fuel. 20*s.* per ton.	41	23

Birmingham 1898. *Royal Agricultural Society.* 46·8-*miles run.* *Agricultural Society* 1898.

Cost of Fuel.		Cost of Fuel per mile per ton.	Wheel tyres.	Gear.	Remarks.	Official No.	No.
Per mile.	For 46·8 miles.						
Pence.	*s.* *d.*	Pence.					
Oil. 0·45	1 9	0·180	S.R.*	Chain and gear	Very good on road. Oil spirit, 7½*d.* per gal.	—	24
Coal. 2·10	7 6	0·300	Iron	Do.	Good on road. 175 lbs. pressure. Coal fuel for boiler, 20*s.* per ton.	—	25
Oil. 2·38	9 3	0·360	Do.	Do.	Few stops. 200 lbs. pressure. Oil fuel for boiler, 4¾*d.* per gal.	—	26
12	13	14	15	16	17	18	19

* S.R. = Solid Rubber.

Discussion on 26th April.

The Chairman said the attendance that evening and the applause which the Paper had elicited was an earnest of the kind of thanks which Professor Hele-Shaw would receive at the proper time. As a statement had appeared in Appendix II (page 233) by Mr. Hoy of the Lancashire and Yorkshire Railway, with regard to the working of a Thornycroft motor-wagon, although Mr. Hoy was not present, Mr. Aspinall was, he thought he could not do better than ask Mr. Aspinall to tell the members whatever was important in his mind about the experience that had been met with at Horwich.

Mr. John A. F. Aspinall, Vice-President, said that all that was known about that particular motor vehicle, which was still in use by the Lancashire and Yorkshire Railway Company, was practically shown in the statement contained in the Paper. His friend, Professor Hele-Shaw, had asked for such figures as were in existence, and they were readily given to him. The consumption of water and of coke were clearly stated in the Paper. How much the vehicle was going to cost for maintenance and repairs in the future could not be told. The fact of the matter was that he determined some months ago to give the subject a thorough trial for the purpose of carrying goods in Liverpool and in Manchester to and from the different railway depôts, and he thought his company could not do better than get one of Mr. Thornycroft's vehicles, although some difficulty was met in inducing him to part with it. He had given instructions for the most careful observations to be made of its work. The results had been fairly satisfactory for some classes of work, but it could not be said that the vehicle was cheaper than horse traction for all work. There were some things for which it was better, and there were some things for which it was not as good as horse work, and, until more experience had been obtained, it was impossible to make a general statement as to its usefulness. He had nothing to complain of with regard to the mechanism of the vehicle, but the whole question of cost was one of which as yet there was no knowledge. He had hoped that the question of costs would be thoroughly thrashed out long before by that most energetic body called the Liverpool Self-Propelled Traffic Association. That association had written many papers and held many meetings, but he did not know they had done anything beyond some experimental trials. Their great object of course was to show that it was far cheaper and better to carry goods between Liverpool and Manchester by means of a motor vehicle than to send them by such a thing as an old-fashioned railway. It was a shame for a railway company to take the wind out of their sails by having the very first steam-driven vehicle in Liverpool, but he had been only too happy to let them have the results obtained, and if any further useful figures were found, he should give them to the Institution. With regard to the curves of which Professor Hele-Shaw had spoken, he was going to ask him how he had made out what was the rate per ton per mile on the railway, as ton-mile figures, in the sense which he had used them, did not exist on English railways. Although the author referred to a parliamentary paper, that parliamentary paper would be found to refer to special things and not to the general goods carried over railways.

Professor Hele-Shaw said the data were taken for Classes 1 and 4 in the Railway Acts of 1891 and 1892.

Mr. Aspinall said that one other remark he would like to make had not to do with the heavier class of vehicle, but with the high speeds of the automobiles which Professor Hele-Shaw had mentioned as used in France. He had been within the last few days staying in a part of France where the motor-car was rampant. Wandering about in the country lanes it was impossible to walk with safety. There were motor-cars in front, motor-cars to the right, and one's only chance of safety was to get into a side ditch. He hoped that the trials of the ordinary motor-car which were being made in England would not result in people going in for shamefully reckless driving such as was found in France, because, if they did, they would imperil what to engineers was of the utmost importance, namely, the starting of a further large engineering industry. It was of the greatest possible importance that the whole of that great manufacture of self-propelled vehicles should not be permitted to fall into the hands of our friends, the French, as engineers in this country were quite capable of making them. He could not help thinking that, if the public began to feel that those vehicles were not safe, it would damage the interests of manufacturers in this country.

The **Chairman** drew attention to the fact that Professor Hele-Shaw had shown diagrams on Plate 29 taken by a viagraph, Figs. 54 to 56, Plate 38. Mr. John Brown, of Belfast, the inventor of the viagraph, was present. He had come a long way, and the members ought to take the opportunity of hearing him speak on the subject. It would be interesting to hear him, especially as he came from Belfast, which was the town from which Mr. Dunlop came, the inventor of the successful tyre.

Mr. John Brown said he felt that both the viagraph and himself were very much indebted to the Institution for the honour of being present. He would not enlarge upon the instrument. A description of it would be found in the Cyclists' Touring Club Gazette for February 1899, in the Proceedings of the Belfast Natural History and Philosophical Society of 11th January 1899, and in "The Surveyor." It was originally designed with a rather philanthropic object. Irish people who had travelled in England had remarked on the excellence of the roads, but they could not say in what way or how much better they were than the Irish roads, and it seemed to him that if an instrument could be obtained to compare one road with another, pressure might be brought to bear on the local authorities in Ireland in order to get better roads.

The instrument, Figs. 54 to 56, Plate 38, consisted of a straight-edge applied to the road surface along which it was drawn. In the middle of it there was a lever carrying a serrated wheel on the free end, which followed all the unevenness of the road, as it was drawn along. This wheel rose and fell over the unevenness, and actuated a pencil which marked on a paper winding round a drum, which drum was also driven by the wheel. The result was a diagram of the surface of the road drawn to full size vertically, and one-eighth longitudinally. Some diagrams reduced very much were shown in the Paper, Plate 29. In addition to drawing the profile, there was an integrator which automatically added up the depths of all the unevenness over which the road wheel passed. The details of the machine could be examined at the close of the meeting. The amount of unevenness in a road might vary from 12 feet per mile on a good English road to 100 feet or more on a bad road in Ireland. There were also bad roads in England, roads which vied with some of the worst in Ireland. Of course it was necessary to compare equal lengths of whatever roads were being operated upon, and an arrangement was placed in the drum by which, after the machine had passed over one-twentieth of a mile, a bell was automatically rung to indicate that this length had been covered. The machine was then stopped to take the indication and mark the diagram.

The Chairman asked up to what speed the instrument was run.

Mr. Brown said it might be drawn by hand, or attached to a vehicle going at a walking pace. There was one scientific application among others, to which he thought the machine might be put, which seemed important, and that was in calculating the extra power required to draw vehicles over rough roads compared to smooth ones. If it was supposed that the wheel of a carriage on descending into a depression or rut did not gain power which would take it out of that rut at the other side, then in comparing two of the roads of which diagrams had been given, the extra power to drive the vehicle on a bad road at seven miles an hour per ton, would be half a horse-power extra on account of the unevenness. Leaving the viagraph he might be allowed to refer to the subject of spring wheels. He would point out that in any wheel of the leaf spring kind, as shown in Fig. 18, Plate 31, it was necessary to be certain that the friction in the spring was not important. In a leaf spring employed in the ordinary way between the vehicle and the axle, the friction between its leaves acted as a kind of brake on the vibrations, after

(Mr. John Brown.)

the manner of what was called a "dash-pot" in some electrical plants; but with springs in the wheels the deflection of such springs occurred at every revolution, whether the wheel was running on a smooth road or a rough road, and the loss due to friction in the spring itself went on all the time, and had to be supplied by the power. He spoke of that because he had recently constructed an electrical car, in which he employed spring wheels. There were a good many other novelties in the car, but he had found in those wheels which were not constructed on the Thornycroft wheel principle, but with helical springs, hooked at the ends to the boss and the hub and crossed, the power absorbed was so great that he had been obliged to modify them altogether, and endeavour to get springs rigidly attached to the hub and to the boss. The difficulty about rigidly attached springs was that the stress was so great at the point of attachment that the spring was liable to break off. He was now endeavouring to overcome that.

Mr. John I. Thornycroft, Member of Council, said the first duty he had was to thank the author of the Paper, who had treated the subject so exhaustively as to leave little to be said. It really seemed to him it had all been summed up in a manner so careful and elaborate that he did not know where to attack the subject. He might say generally that the Paper was one of uniform merit, but there were some statements about the life of wheels in which he could not quite concur. He liked the description of the theory of the pneumatic tyre as absorbing an obstacle, and if it could be really worked out so as to give satisfactory results for motors carrying heavy loads, then the difficulty of the roads would be overcome. The viagraph, which measured the inequalities of roads, and brought home a sense of the very bad roads which had to be travelled over, and how very much locomotion was impeded by preventable causes, might lead to another solution, which was very desirable. With regard to the wear and tear of wheels which had been dwelt upon, he was sorry he did not quite concur with Professor Hele-Shaw in his view. The wheels with which he had experimented very recently had given results which seemed to him to be reasonable.

The first experiments were made with steel wheels, which were certainly not successful, but taking ordinary wheels, built with plenty of wood in them, the result was that the fore-wheels lasted remarkably well, and there was very little to say against them. In attaining the extreme speed which Mr. Aspinall had spoken of as undesirable, it was very necessary to use something other than the ordinary wheel. But he thought it was most desirable that people should not go beyond the present speed-limit, and cause trouble in that direction. For ordinary speeds, the steering wheels ran perfectly well, and required no attention whatever, certainly during the first two or three years of running. With regard to the driving wheels, when they were really made strong for their weight they lasted a long while, and the only thing found to give any trouble was the tyre, which also had a reasonable life, requiring attention about once in six months only. When the roads were hard and lumpy, the shocks due to the inequalities in the road caused trouble which was quite unknown with the locomotive, and the comparison between the locomotive, where the weight had been greatly increased with advantage, could not be employed with regard to vehicles travelling on ordinary roads. There one had to recognise the very great difficulty, which was represented graphically in the Paper (page 191) by the comparisons showing the extremely large resistance on a road which had not an even surface, and which sometimes was of a sandy nature. A "Scotch" in front of the wheel was a very moderate thing compared to sand. Obstacles which looked extremely difficult might be run over at a moderate speed without much difficulty, whereas in sand a vehicle might as well be travelling in some adhesive substance, and the whole thing seemed to be anchored; it was impossible to get up any momentum in this case. That led to the necessity for lightness and very great power for the weight. It had been proved that the cost of power, that is, for fuel and water, was not so great as to embarrass very seriously the movement of goods over a common road. Other expenses were relatively great as compared with that of power. Although a motor had to climb up steep hills which on a railway would be quite impracticable, still it was possible on a common road to work over hills which were not

(Mr. John I. Thornycroft.)

practicable with horses. He thought that with proper legislation, so as not to embarrass what was being done, it was probable that the industry would rapidly grow to very great proportions. He would not trouble the members by going into details on the subject, because, as he said, they had all been so well dealt with in the Paper that he felt he had nothing further to add. [*See also page* 282.]

The CHAIRMAN pointed out that the correct time of closing had arrived, but he felt there was so much room left for discussion of the Paper that it had better be adjourned until the next meeting in June, when the members would have the benefit of knowing the results of the 1,000-miles run that was now going on, and would also have the pleasure of the presence of a number of American Engineers, who would be the guests of the Institution at that time and would no doubt state the latest news upon the subject. Before the members dispersed they should at least convey a formal vote of thanks to Professor Hele-Shaw for his Paper, and he would therefore ask some gentleman who felt that he had something he wished to say, and who might not be able to come again in June, to take the opportunity of rising and proposing a vote of thanks, and some other gentleman in similar circumstances might second it.

Mr. E. SHRAPNELL SMITH, Honorary Secretary of the Liverpool Self-Propelled Traffic Association, in moving a vote of thanks to Professor Hele-Shaw, wished to reply to the remark made by Mr. Aspinall, that he had not heard anything lately of the Liverpool Self-Propelled Traffic Association. He wished to assure the members that the Association was still in existence, and would be heard of again in the near future. It was of considerable interest to hear from Mr. Aspinall that good results had been obtained from the Lancashire and Yorkshire Railway motor vehicle upon intermittent work at short distances, where long waits were incurred, and where the high capital value of the motor placed it at a disadvantage. He might mention that the Corporation of Liverpool had a motor vehicle many months before the Lancashire and Yorkshire Railway, as had also several firms in Liverpool. His view was that the company purchased that vehicle because they were getting a little nervous, and wanted to see what a motor vehicle would do. There was to be another competition in May 1901. In France heavy vehicles were becoming fewer and fewer, whilst in this country they were growing more and more numerous, and he thought every confidence might be felt in the future of the heavy traffic movement here. He had come up specially from the 1,000-mile tour which was now being carried on by the Automobile Club, and he hoped to return that evening. There was a general feeling among the members of the Club on that tour that they were suffering a severe loss in not being present that evening. He refrained from any discussion of the Paper at that juncture, but felt the Institution had done a service to the whole movement in having the Paper, and proposed a vote of thanks to Professor Hele-Shaw for having prepared it. [*See also page* 311.]

Professor C. VERNON BOYS seconded the vote of thanks to Professor Hele-Shaw for his excellent and valuable Paper; and the motion was carried with acclamation.

Professor HELE-SHAW, in mentioning the subject of cost, said that the owner of a motor-car in the 1,000 miles trial now proceeding had informed him that in estimating the working expenses he considered it about a halfpenny per mile for petroleum spirit to run the motor, and somewhere about twopence for wear of the pneumatic tyres. He then thanked the members for the way in which they had listened to his Paper, and the reception they had given him that evening.

SUPPLEMENTARY PAPER ON THE RECENT 1,000 MILES ROAD TRIALS.

By Professor H. S. HELE-SHAW, LL.D., F.R.S., *Member*, of Liverpool.

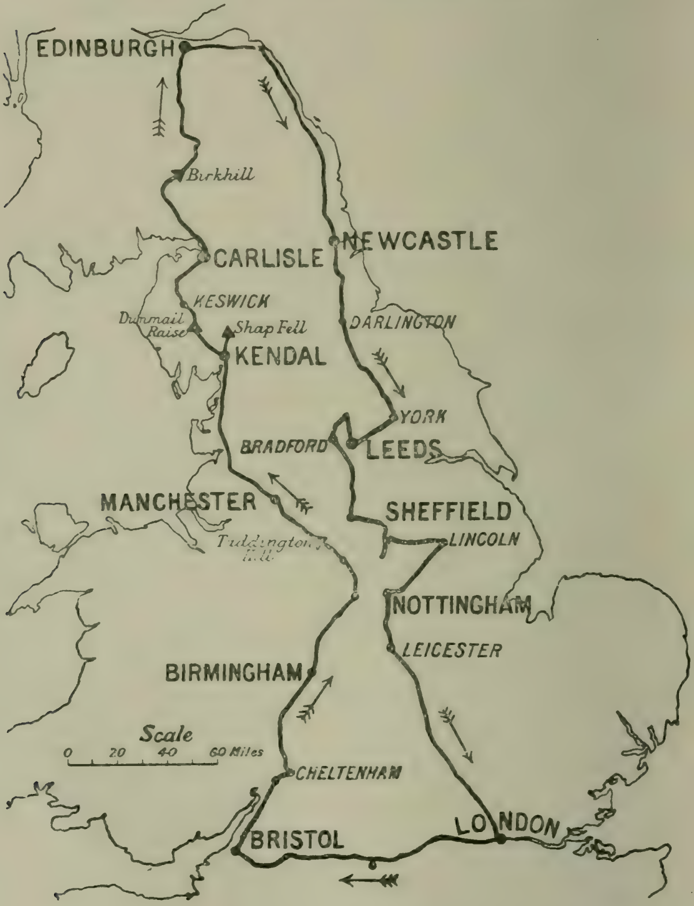
In the foregoing Paper attention was called to a most important trial of light self-propelled vehicles which was at that time being carried out. This trial has proved very successful, and has demonstrated in a remarkable way not only the wonderful progress which has been made towards the perfection of the motor carriage, and the great public interest felt on the subject judging by the crowds who lined the streets in the large towns and gathered even along the country roads, but also has undoubtedly been the means of eliciting much valuable information. Although its main features will be known to members through the public press, it has been thought desirable that the author should give a brief summary of the trial and its results.

The credit of the satisfactory carrying out of a road trial of 1,000 miles, in which a large number of vehicles have visited, and been exhibited in, the chief towns of the country, and passed through some of the most beautiful scenery, thus enabling a comparison to be made of the special features and actual performance of the numerous types of motor-cars now before the public, is due to the Automobile Club of Great Britain. Some idea of the care with which the rules and regulations were drawn up, the completeness of the contour and other maps, as well as of the road instructions, may be realised from the fact that the Official Programme—a copy of which will be found in the Institution library—consists of a volume of more than 200 pages. It may be fairly said that it was the great object of the club, as well as of all who took part in the trials, that nothing should occur to hinder the progress of a movement, the development of which not only promises much enjoyment, for the users of both private and publicly owned vehicles, but also solid commercial benefits from the use of light vehicles for trade purposes, and the growth of a new and important industry in this country.

The map, Fig. 58, shows the route, with the towns where each stop was made for the night after a day's run indicated in larger letters, these towns being Bristol, Birmingham, Manchester, Kendal, Carlisle, Edinburgh, Newcastle, Leeds, Sheffield and Nottingham. Although there were only eleven days of actual running, the tour really extended over three weeks, exhibitions lasting a full day being held (with the exception of Kendal) at the above towns. There were also exhibitions of from one to three hours' duration at other places *en route*, namely Cheltenham, Keswick, Darlington, York, Bradford, Lincoln and Leicester.

Advantage was taken of the contour of the country at certain places to have hill-climbing trials: at three of these places, namely, Taddington, Dunmail Raise, and Birkhill, all competing vehicles had necessarily to make the ascent, as the hills formed part of the route, and all did so successfully, while the speed tests on Shap Fell—which were optional—were successfully undertaken by twenty-six of the vehicles. The results have been carefully tabulated by the Automobile Club, and are reproduced in Table 5 (pages 260–265) and it will be seen that while the average speed in these steep ascents was in all cases ample for all requirements of touring and pleasure, the possibilities of high speed under such circumstances by modern motor vehicles are abundantly proved. Thus the car of the Hon. C. S. Rolls was able to take the steepest of these ascents at 16 miles an hour, while the first and longer part of Shap Fell was taken at the almost incredible speed of no less than 27 miles an hour, the long and steep ascent of Dunmail Raise being made at 20½ miles an hour. In the case of Taddington, Dunmail Raise, and Birkhill, Mr. Rolls had the usual complement of four passengers on his car. It may be stated that in the Shap trials vehicles were made to stop at the dip between the two portions of Shap Fell, and to ascend the steeper portion from a standing start, under which circumstances the average speed of nearly 18 miles an hour on the latter was attained by Mr. Rolls. This performance is all the more remarkable, since the official weight of this car unloaded was more than a ton, while the trials were not made after any special preparations, but as a part of the ordinary day's run on a long tour.

Fig. 58. *Route of* 1,000-*Miles Road Trial, April* 1900.



Coming to the general statement of results, it may be said that eighty-three vehicles entered, out of which eighteen did not start. Amongst the starters there were no electric vehicles, and only two steam, and of these only one, namely, the Stanley Steam-Motor Car, ran through the entire trial. The vehicles, with the above exception, were driven by petroleum spirit motors, and the results showed the entirely trustworthy nature of this motor and how admirably it is adapted for the employment on light vehicles. The following is a brief tabulated summary of the general results:—

Type of Vehicle.	No. Entered.	No. Started.	Vehicles with average speed throughout the trials of			Off the road one or more days.	No. Failed.
			12 miles.	Above 9.	5 to 8 m.		
Carriages . .	48	33	7	15	1	8	2
Voiturettes . .	26	24	3	8	2	7	4
Motor Cycles .	9	8	2	1	—	3	2

It may be interesting to put the above particulars in another form, and the following Table gives the details of the trial, dividing the vehicles into those owned and driven by private individuals, and those entered by manufacturers.

Vehicle.	No. Entered.	No. Started.	Vehicles with average speed throughout the whole trial of			Off the road one or more days.	No. Failed.
			12 miles.	Above 9.	5 to 8 m.		
Privately owned and driven .	29	20	6	7	1	4	2
Entered by Makers .	54	45	6	17	3	13	6

Altogether about fifty vehicles, out of sixty-five which originally started, formed into line at St. Albans in order to run together into London to complete the tour, at the buildings of the Automobile Club.

Of those who actually broke down, in one case the crank-shaft was broken; in another there was a fractured piston-rod and broken counter-shaft; in another the steering axles were fractured; in another the parts were strained in consequence of a collision with a wall. One of the two steam vehicles failed owing to a cylinder head breaking, but it returned safely to London; in another case the front axle bent through excessive strain; another broke its cross-head and wore the cylinders; in another vehicle the frame and wheels turned out to be faulty and would not stand the wear of the run, while in one the body of the vehicle itself (i.e. the woodwork) gave way.

All engineers are aware that such failures as these are only to be expected in any new class of machine, particularly where the vibrations and strains are so exceptional as in the case of a vehicle running at a high speed upon the common road, and where the weight of every working part must necessarily be reduced to a minimum; but the entire absence of anything like a severe accident from any break-down of the working parts in the run, where no vehicle did not at some time or another attain a speed of at least 25 miles an hour upon the road in each day's run, whilst many far exceeded that speed, must be regarded as a most encouraging result.

Although in general no official recognition was made of any speed above the legal limit of 12 miles an hour, it was well known that speeds exceeding 40 miles an hour were attained upon roads free from other traffic; in one case a well-known vehicle successfully raced an express train for several miles. What can be done in this direction by the modern motor carriage is however best illustrated by the result of the road race between Paris and Lyons, in which the winner, M. Charron, covered 353¾ miles in nine hours eight minutes, thus beating the express train, which takes eight hours fifty-three minutes to travel the shorter route of 320 miles.

The pneumatic tyre and its advantages have been considered at length in the Paper, and it is interesting to note that with one or two exceptions all the vehicles in the run employed this type of tyre. There is little doubt that the general freedom from failure of the working parts was largely due to the use of such tyres, and as far as could be gathered upon the various parts of the run, these tyres had on the whole given remarkably little trouble, nor had the results of wear been anything so great as had been expected, and the tyres of most of the cars at the end of the 1,000 miles run, appeared, as far as could be ascertained from inspection, very little the worse for wear.

Probably the most important lesson of the whole trial was the absolute necessity for constant care and attention in order to obtain such results as have been recorded, and in view of the general introduction of the motor vehicle for pleasure purposes, the necessity for skilful attention cannot be too strongly urged in order to avoid not merely exasperating delays, but possible breakdowns which might cause something more than a mere annoyance.

TABLE 5 (*continued on opposite page*).

Automobile Club 1,000 *Miles Trial, 23rd April to 12th May* 1900.

HILL-CLIMBING COMPETITIONS.

No.	Description.	Horse-power.	Weight.		Taddington. 27th April.		Shap Fell, No. 1. 30th April.	
			cwt.	qrs.	Miles per hour.	No. of passengers.	Miles per hour.	No. of passengers.
1	Benz Ideal	3	10	3	5·39	2	—	—
2	Benz Ideal	3	10	2	7·18	2	11·5	2
3	Locomobile Steam Carriage	2	6	3	9·76	2	6·0	2
4	Gladiator Voiturette	3¼	5	2	8·17	—	—	—
5	New Orleans Car	3	6	0	6·30	2	—	—
6	New Orleans Car	3	—		6·05	—	—	—
7	Décauville	3½	6	1	6·70	—	—	—
8	International Victoria	3	—		5·29	2	—	—
9	International Victoria	3	—		6·17	2	—	—
10	Star Voiturette	3½	—		9·15	2	—	—
11	Roots and Venables	2⅞	—		5·80	—	—	—
12	De Dion Voiturette	3	—		—	—	13·5	—
13	De Dion Voiturette	3	7	0	10·08	2	14·5	2
14	Marshall Carriage	5	12	3	—	--	11·5	2
15	M.C.C. Triumph	3½	6	2	9·45	—	—	—
16	M.C.C. Triumph	3½	—		7·56	—	—	—
17	Wolseley Voiturette	3	13	0	10·08	2	13·0	2
18	Marshall Carriage	5	12	1	4·94	2	10·5	2

(*continued on next page*) TABLE 5.

Automobile Club 1,000 *Miles Trial, 23rd April to 12th May* 1900.

HILL-CLIMBING COMPETITIONS.

Shap Fell, No. 2. 30th April.		Dunmail Raise. 1st May.		Birkhill. 2nd May.			No.
Miles per hour.	No. of passengers.	Miles per hour.	No. of passengers.	Miles per hour.	No. of passengers.	Remarks.	
—	—	5·01	2	6·0	2	Both out temporarily.	1
4·80	2	6·64	2	6·6	2	Both got down temporarily.	2
6·64	2	9·79	2	10·9	2		3
—	—	7·67	2*	7·5	2	Both out temporarily.	4
4·42	1	6·22	2†	7·7	2		5
—	—	4·74	1	—	2	One passenger out for a time.	6
—	—	5·13	1	—	—		7
—	—	5·55	2	—	—		8
—	—	6·04	2¶	4·1	2		9
—	—	—	2**	8·0	2		10
—	—	—	—	—	—		11
7·24	—	9·79	—	10·9	2		12
7·58	—	—	—	8·2	—	One alighted near commencement to adjust contact breaker.	13
4·42	2	—	—	—	—		14
—	—	9·33	—	9·6	2		15
—	—	7·33	2	—	—		16
6·37	2	7·90	2	8·6	2		17
4·54	2	6·04	2	6·3	2		18

* One off temporarily. † Both alighted temporarily.
¶ One off temporarily. ** Both alighted.

TABLE 5 (*continued on opposite page*).

Automobile Club 1,000 *Miles Trial*, 23*rd April to* 12*th May* 1900.

HILL-CLIMBING COMPETITIONS.

No.	Description.	Horse-power.	Weight.		Taddington. 27th April.		Shap Fell, No. 1. 30th April.	
			cwt.	qrs.	Miles per hour.	No. of passengers.	Miles per hour.	No. of passengers.
19	M.M. Co.'s 6-h.p. Phaeton	6	21	3	5·29	3	10·5	3
20	M.M. Co.'s Iveagh Phaeton	6	20	3	5·49	4	10·5	3
21	Brown Whitney Steam Car	—	—		4·56	3	—	—
22	8-h.p. Peugeot	8	17	0	9·45	2	—	—
23	6-h.p. Daimler	6	19	0	6·30	2	13·5	2
24	6-h.p. Daimler	6	21	0	6·55	—	13·5	—
25	Daimler Parisian	6	19	1	9·15	—	16·0	—
26	Richard Car	7	16	0	—	—	—	—
27	Richard Car	7	16	0	6·43	4	—	—
28	Lanchester Carriage	8	—		8·62	—	11·5	2
29	M.M. Co.'s Tricycle	2¼	—		—	—	—	—
30	Simm's Motor Wheel	2¾	—		9·45	1	—	—
31	Century Tandem	2¼	—		—	—	—	—
32	Ariel Quadricycle	3⅛	4	0	15·13	2*	20·5	2
33	Ariel Tricycle, with Whippet attachment	2¼	3	0	14·40	2	20·5	2
34	Benz Ideal (Mrs. Bazalgette)	3	10	0	6·70	2	—	—
35	Mors Voiturette (Mr. Phillips)	4	11	0	8·39	2	—	—
36	6-h.p. Panhard (Mr. Butler)	6	19	0	5·69	3	10·5	3

* Assisted with pedals.

(continued on next page) TABLE 5.

Automobile Club 1,000 *Miles Trial*, 23*rd April to* 12*th May* 1900.

HILL-CLIMBING COMPETITIONS.

Shap Fell, No. 2. 30th April.		Dunmail Raise. 1st May.		Birkhill. 2nd May.			No.
Miles per hour.	No. of passengers.	Miles per hour.	No. of passengers.	Miles per hour.	No. of passengers.	Remarks.	
5·14	3	5·86	3	6·5	3		19
4·42	3	5·13	4	6·3	3	One passenger walking steep portion.	20
—	—	7·67	3*	8·9	3	One out temporarily.	21
—	—	9·79	2	10·9	2		22
6·37	2	7·90	2	6·8	2	A third passenger walked all the way up.	23
4·42	—	6·64	4†	6·6	3		24
—	—	8·92	—	8·0	3		25
—	—	7·67	4	7·5	4	One passenger walked for a few yards.	26
—	—	5·86	4	5·0	3	All out temporarily.	27
4·98	2	6·84	2	7·7	2		28
—	—	7·90	1	12·6	1		29
—	—	—	—	—	—		30
—	—	2·1	2¶	10·9	2	No pedals. Both off at finish.	31
6·12	2**	11·41	2††	13·3	2	Passenger alighted for about 20 yards.	32
6·64	2¶¶	8·22	2	12·6	2	Had to dismount and push.	33
—	—	4·66	2	—	—		34
—	—	7·67	2	7·5	2		35
4·80	3	6·22	3	5·7	3		36

* Two alighted temporarily. † One alighted for 20 yards. ¶ No pedals, both walked last part. ** Passenger alighted, and driver pedalled over last portion. †† Both walked for 50 yards. ¶¶ Both alighted and pushed at finish.

TABLE 5 (*continued on opposite page*).

Automobile Club 1,000 *Miles Trial, 23rd April to 12th May* 1900.

Hill-Climbing Competitions.

No.	Description.	Horse-power.	Weight.		Taddington. 27th April.		Shap Fell, No. 1. 30th April.	
			cwt.	qrs.	Miles per hour.	No. of passengers.	Miles per hour.	No. of passengers.
37	6-h.p. Panhard (Mr. T. B. Browne)	6	17	0	8·17	3	13·0	2
38	6-h.p. Daimler (Mr. A. Harmsworth)	6	—		—	—	—	—
39	8-h.p. Napier (Mr. E. Kennard)	8	22	1	13·74	3	19·0	2
40	6-h.p. Daimler (Mr. H. Edmunds)	6	—		6·43	2	—	—
41	6-h.p. Daimler (Mr. E. Pitman)	6	—		—	—	11·0	2
42	6¼-h.p. M.M. Co.'s Phaeton (Mr. Cordingley)	6¼	—		6·30	—	—	—
43	6-h.p. Daimler (Mr. C. K. Gregson)	6	22	0	5·80	—	—	—
44	6-h.p. Daimler (Mr. J. D. Siddeley)	6	18	0	8·39	2	13·0	—
45	6-h.p. Daimler (Mr. W. Exe)	6	19	2	8·17	3	11·5	3
46	8-h.p. Panhard (Mr. Mark Mayhew)	8	—		10·08	1	12·0	1
47	12-h.p. Daimler (Hon. J. S. Montagu, M.P.)	12	—		11·19	3	—	—
48	12-h.p. Panhard (Hon. C. S. Rolls)	12	21	1	17·77	4	27·5	2
49	12-h.p. Daimler (Mr. J. A. Holder)	12	25	1	14·40	4	—	4
50	12-h.p. Daimler (Mr. J. Hargreaves)	12	—		6·3	—	—	—
51	7-h.p. Peugeot (Mr. Mark Mayhew)	7	—		7·74	2	15·5	2
52	Ariel Tricycle (Mr. A. J. Wilson)	2¼	—		18·91	1	18·5	1
53	Empress Tricycle (Mr. H. Ashby)	2¾	—		—	—	20·0	1
54	Enfield Quadricycle (Mr. E. M. Iliffe)	2¼	—		9·15	2*	—	—

* Passenger alighted for 100 yards.

(*concluded from page* 260) TABLE 5.

Automobile Club 1,000 *Miles Trial, 23rd April to* 12*th May* 1900.

Hill-Climbing Competitions.

Shap Fell, No. 2. 30th April.		Dunmail Raise. 1st May.		Birkhill. 2nd May.			No.
Miles per hour.	No. of passengers.	Miles per hour.	No. of passengers.	Miles per hour.	No. of passengers.	Remarks.	
5·68	2	7·90	3	8·6	3		37
—	—	4·66	2	6·6	2	One out temporarily.	38
—	—	13·69	3	11·5	3		39
—	—	7·08	1	—	—		40
4·42	2	6·22	2	4·8	2	Both had to push.	41
—	—	—	—	—	—		42
—	—	6·84	3	4·1	3	One walking.	43
4·82	—	6·92	2	7·0	2	Dropped off for 2 yards to look at pump.	44
5·68	2	7·90	4	8·2	4		45
5·48	1	—	4*	—	—		46
—	—	5·26	3†	10·4	2		47
17·71	2	20·54	4	16·0	4		48
7·24	4	10·27	4	10·9	4		49
—	—	6·41	—	—	—		50
7·97	2	9·79	2	10·0	2		51
—	—	5·13	1	6·8	1	Had to push up.	52
15·94	1	17·06	1	7·5	1		53
—	—	9·33	2¶	12·0	1	Passenger off, driver pedalling.	54

* All had to alight. † Two passengers walking.

¶ Dropped passenger on steep portion.

Discussion on 27*th June* 1900.

Mr. E. J. CHAMBERS wished to say a few words upon the interesting addenda to the Paper that had been read at the previous meeting. He had not been able to be present, but had read the summary of what was said at that meeting. During the last three months he had been driving a "Panhard" motor car, and that machine had performed some considerable work. It had been used day by day for all sorts of purposes, and with the very best results. He thought that the Institution had a considerable work before it, which it might take up with very great advantage to the engineering trade of this country. There was a great deal of opposition throughout the country to the use of motor cars; and no doubt that legislation had prevented the adoption of that kind of traffic for a good many years, with the result that competitors abroad had practically made the running in that line. The car he had been driving was bought in France, although he believed there were equally good cars made in this country. But the great difficulty met with in going about the country—and he was speaking as a man who owned horses and drove them, and was very fond of them, and as one who had the greatest sympathy with all others who drove horses—the greatest opposition met with was from the attendants of horses that were met with on the roads. The members could all remember what a great opposition there was to the introduction of the bicycle. Most people looked upon it as a great nuisance. He wondered what the trade of this country would have been if the bicycle had not fought its way to the front. He was quite sure that if the same opposition was maintained, that now existed in reference to the use of the motor car for pleasure and business purposes, it would hinder very much the motor industry in this country. Therefore he would suggest that the Institution should take a leading part in preventing any undue opposition, any unfair opposition, on the part of the general public, and especially of the legislators, and at the same time he would suggest that anything like extreme high speeds on the common roads should be discouraged in every way possible. There was no object whatever in rushing from place to place in a motor car to see how quickly the journey could be done. He did not say there should be no trials to test the machinery, but there was no reason in tearing from place to place. Horses were driven frequently at 15 miles an hour by those who happened to own good ones, and he did not think that 12 miles per hour was a fair limit for a motor car; but at the same time it was necessary to go by degrees. He had a partner who unfortunately bought a motor car the other day—he was not going to say where he bought it, because it would not be fair to the makers—and he had the misfortune to turn the car over, and in about five or six minutes from that time his car, as far as it could be, was burnt up. He wished to point out to makers of motor cars that if that sort of thing was going to happen, motor cars would very quickly get their quietus from the general public, quite apart from the opposition of those who did not want to buy them. It must have been an absolutely wrong design that could possibly have had such a result as that. He should have a very great objection to turning the "Panhard" car over, but he was certain that if it did turn over there would not be the slightest risk of it burning up. The tank which supplied the cylinders with the motor spirit was quite free from any possibility of being set alight. The two ignition tubes were quite away from anything but a very small supply of spirit in a separate cylinder, and nothing of the kind that happened to the other motor car could happen to this. A limb or two might be broken if the car should chance to overturn, but that would be all—the car would not be wrecked. He pointed out to makers that they must study very carefully the safety of their cars. Another thing they must study was the little conveniences necessary in carriages. He was sorry to say there was a great lack of convenience in motor cars. He had looked at a great many of them, and had had a great many alterations made in the "Panhard" car since he had bought it. There was a fine opportunity for engineers and coach builders to bring out, not only a good looking car, but one that was free from the great many defects which naturally arose from new machinery.

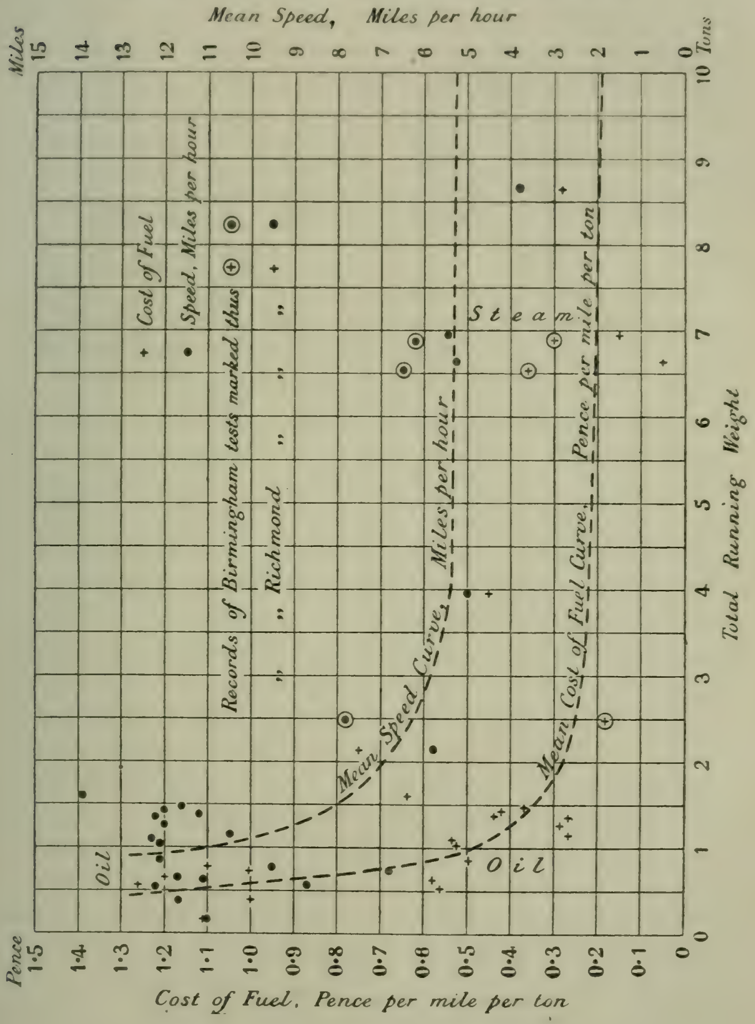
(Mr. E. J. Chambers.)

He did hope that the motor car industry would not be hampered by legislation, and that the Institution would take some steps to prevent that occurring.

Mr. Bryan Donkin, Member of Council, said he had had the pleasure of reading the interesting Paper of Professor Hele-Shaw, and had added a Table (page 240) giving some tests of oil and steam carriages at Richmond by the judges of the Automobile Club, and also tests at Birmingham by the judges of the Royal Agricultural Society. He had also prepared a diagram, Fig. 59, from Table 4 (page 240) with regard to the cost, the object of which was to arrange, or attempt to arrange, in order of merit, the cost in pence for the fuel or oil per ton mile of total running weight, including fuel, passengers, &c. He was afraid it was rather a poor attempt, but it would be seen that there was a certain law. Horizontally the scale was in tons total running weight, and vertically the cost of fuel in pence per mile ton. It would be seen at once that the cost of the fuel was very much greater with the lighter and higher speed vehicles, and very much less with the heavier and slower vehicles. In Table 4 the carriages had been arranged in order of merit, the most economical carriage coming first, and the least economical last. Apart from the question of fuel and oil, there were the other very important questions of safety, comfort, good running, steering, cost of repairs, tyres, and freedom from breakdown, which were very much more important than the cost of fuel per ton per mile. But as it was extremely difficult to represent them graphically, the attempt had been made to plot only the cost of fuel. Generally speaking, road locomotion was a much more difficult problem than tramway or railway traction. There were all kinds of roads and hills to deal with. During the last five years great improvements had been made in vehicles for light and heavy traffic with oil, steam, and electric carriages, but he thought engineers ought to recognise the fact that great defects still existed, and that they should be very carefully considered with a view to future improvements. Professor Hele-Shaw had given some particulars of the 1,000 miles endurance trial, made under the auspices of the Automobile Club. About sixty-five

Fig. 59. *Oil- and Steam-driven Motor-Carriages. Trials at Birmingham,* 1898; *and Richmond,* 1899.

See Table 4 (columns 4, 11 and 14), by Mr. Bryan Donkin.



(Mr. Bryan Donkin.)

vehicles started from London and forty-six returned, having completed the 1,000 miles. That was relatively a very good percentage. He might be permitted briefly to point out the chief defects of the present motor cars. First and foremost was the noise, which was serious. It seemed to him that the chief cause of the noise—and he had ridden in a good many motor cars—was the gearing for the reduction of speed. It was necessary to reduce the speed of the motors from 1,500 to 2,000 revolutions per minute to the number required for the speed of the driving-wheel on the road. Four forward speeds and one backward were very usual. There was the worm and worm-wheel gear of Mr. Lancaster, which seemed a good solution. One of the difficulties was, that every five or ten minutes, according to the character or ups and downs of the road, the speed had to be altered, which caused a considerable jerk. With oil, steam, or electric carriages, going at an average speed of 10 to 12 miles an hour, there was not very much difference as to this question of noise. It would be very interesting if engineers (including their American friends) could give some gauge of noise. There were gauges of pressure and of vacuum, but at present there was no gauge for noise. If the varying degrees for noise could be registered, it would be an additional advantage. The next great defect was the vibration or trembling of the whole carriage. It was not felt by the passengers during the first 10 to 15 miles, but it was especially disagreeable after the car had been driven about 30 to 40 miles. There was much jolting on the best roads whether the motor was oil, steam, or electric. It was very trying and uncomfortable, after riding many miles, particularly when running at 12 miles an hour and over. The chief cause again was the gearing, and he believed also the want of balance of the revolving parts of the motor at very high speeds of rotation. The third defect was the smell. He was afraid the oil motors were the greatest sinners in that respect; electric motors had very little smell. With steam motors a chief objection was the smoke from the coal or oil, and the appearance of non-condensed steam, which should be condensed or rendered invisible. All these things were very unpleasant to the eye, but not so much to the nose. To sum up the three classes of vehicles, it seemed to him that oil motors were best adapted for long, continuous journeys and for light roads, as oil and spirit could be obtained anywhere. As would be seen by the diagram, Fig. 59, page 269, steam motors to carry 7, 8, or 9 tons total weight, or a load of 5 or 6 tons useful weight, were more suitable for heavy loads. Coke or coal and water could be had in most village towns. With regard to electric carriages, they were more suitable for short town journeys, but the weight of the accumulators —one-half to one ton—and the time required to charge them were much against them. All three classes of vehicles wore the roads however very much less than horses' hoofs. Another important question was with regard to the indicated power and the useful power. There were no good experiments at present on that point, namely, to determine the difference between the power in the cylinders—which were generally two and sometimes four—and the power available at the circumference of the driving-wheels. The loss in friction would be about half, or 50 per cent. With regard to French experiments, some excellent tests had been made upon the consumption of oil and the brake horse-power. It would be interesting if those experiments could be summarised for the Institution. The diameter, stroke, revolutions, and brake horse-power, were recorded, and some of the tests* were very carefully made. He might add that in France, where they had taken the automobile question up much earlier than had been done in this country, there were about 600 makers of road carriages of all types, and some 6,000 private owners of carriages. He had been in Paris in the previous week, and had carefully studied the collection of automobile carriages there, of which there were from 130 to 150, excluding motor bicycles and tricycles. The oil motors, however, were by far the most numerous. There were a good many electric motors, and some few steam motors, especially for parcels; but, taken as a whole, he did not think that there were very many novelties to mention. The engines seemed very similar, especially those of the oil carriages.

Mr. HARRY E. JONES said he would like to give a word of advice to autocar builders from the point of view of adapting themselves to

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* "Revue Technique," 25 Jan. 1900. (One of a series of articles.)

(Mr. Harry E. Jones.,

the traffic which at present occupied the roads, and which could not be got rid of. First of all they must build motor cars like ordinary carriages, so that the horses would not be terrified. A terrified horse was a greater danger to human life than a vicious horse in crowded streets. They must get rid of the unwholesome smell, and he knew from personal experience that horses shied at bad smells. He might also be frightened by the sight of a very unusual vehicle tearing along the road, or by noise and clamour, to say nothing of smoke, and things moving at great speed. It was necessary for people who used roads to know what the rules of the road were, and what were the characteristics of others who used the roads, and of the animals met with on them. Last Saturday he was driving a team of horses, and met a motor car tearing along at 15 or 16 miles an hour. Now he did not think it fair to drive at more than 8 or 9 miles an hour. He held up his whip, but the man drove on, and nearly put him (the speaker) into the ditch beside the common. On Sunday he was riding a young horse from church, and meeting a car, his young animal began to show great excitement. He held up his hand and the man stopped, while he proceeded. The difference was that in one case the driver had some consideration for the safety of other people, and in the other case he had none.

Mr. Henry Sturmey said that before dealing with the Paper he should like to say a few words in reply to what Mr. Jones had just said. He thought that those who used horses must be content to recognise the fact that they had no prescriptive right to the use of the roads. The new form of locomotion was coming indeed: it had come, and it had come to stay, and the sooner those who used horses recognised that fact and saw that their animals were properly broken in to the new conditions of traffic, the sooner would they be able themselves to drive upon the roads in comfort and without fear. He thought most owners and drivers of motor cars were either horse owners and drivers themselves or were bicyclists, and consequently were well acquainted with the rules of the road. He was quite certain they had all made themselves well acquainted with the law upon the subject. Mr. Jones was evidently not quite clear upon the law himself, although he referred to the fact that some automobile people were not acquainted with the law, because in the first place he said he held up his whip and the car was not stopped, and in the second place he held up his hand and the car was stopped. In the second place it was perfectly correct. The law said the hand was to be held up and not the whip. He might further say that any autocarists, who had had any experience, knew that under many circumstances it was far safer for the car not to stop. Although the law laid down the hard and fast rule that if the hand were held up the car must be stopped, in many cases an autocarist who understood horses himself, and who had had experience with horses from the aspect of his own driving seat on the car, knew that both for himself and for the horse vehicle it would be far safer for him at times if he did not adhere to the set rule of the road. Therefore autocar drivers must be allowed to take a little latitude under certain conditions.

With regard to the very interesting Paper of Professor Hele-Shaw, he would like to make one or two remarks. It was so exhaustive that it could not be discussed in detail, and he hoped that the Institution would in future take up some of the special details relating to car construction, and thoroughly thrash them out. In the first place, Professor Hele-Shaw said that a point had now been reached when the motor car should receive the careful attention of mechanical engineers. He did not know why the author said *now*, he thought it should have received more attention from mechanical engineers four or five years ago. It had received the attention of several engineers of well-known ability, for instance Messrs. Thornycroft, and they were to-day reaping the benefit of the attention which they had given to it in a sound and rapidly extending trade. Therefore he thought it would have paid engineers to have given attention to the question long ago. Anyway it was never too late to mend, and he hoped that attention would be given to it now. On the question of railway charges and the comparison of motor cars with railway service, a question which was dealt with in the Paper, page 224, the comparison was made solely with regard to the heavy vehicles in the conveyance of goods. He would like to point

(Mr. Henry Sturmey.)

out that with the lighter vehicles for the conveyance of passengers, time—and time was money—was saved over the railway, broadly speaking, upon any distance—except perhaps upon main lines—up to 50 miles. In nearly all cases, with a suitable car, time could be saved over such distances. For instance, at Whitsuntide he came back with a friend from Cambridge to London, and they were in London, after slowing down and passing through all the traffic, two hours and a half from the time they started, the distance being something like 60 miles. He thought he saved about 20 minutes on the time it would have taken to travel by train, including the going to the station and from the station, to and from the starting point and destination. Upon shorter distances, of course, the difference was really greater. The author had emphasised the effect of road surface upon the vehicles themselves, and there could be no doubt that the road question was a highly important one. The mechanical difficulties of dealing with a vehicle, which had to travel upon all the varied conditions of road which existed in this country, were so enormously greater and different to what they were when only a smooth roadway had to be dealt with—when their paths were made plain and smooth for them—that it was almost incalculable. What engineers had to consider in designing the cars was the enormous amount of shaking about and the multitudinous cross-strains which were thrown upon the mechanism. He would not say they could not be calculated, but they had not been calculated, and hitherto it had been largely a case of rule of thumb. To a certain extent that could not be helped, and he was afraid that must be always so in many particulars, but the designing of a car without considering those cross-strains would be bound to result in failure. He understood that in America—perhaps some of their American friends who were present that morning might be able to enlighten them on the subject—it was now proposed to lay down steel roadways for cycle and motor traffic, and that the cost of laying those roadways would be no greater than the cost of laying good macadam roads. That was a point which he thought well deserved the attention of road engineers. At present either pneumatic tyres or rubber tyres were used (pneumatic tyres on the lighter cars), and there could be no doubt that the use of such tyres, expensive as they were, saved an enormous amount of strain and wear upon the machinery. Although he was not connected with the manufacture now, he was three or four years ago, and at that time there was an idea that for goods wagons, where silence and comfort were not of particular importance, iron tyres would do very well; but it was found that by using iron tyres the machinery was very much shaken about, and the engine put out of running to such an extent that it was virtually impossible to use them. He was speaking of oil-engined cars. Therefore rubber tyres were fitted to the front wheels which supported the motor, the driving weight being supported by the ordinary iron tyres, and that gave much better results. Of course better results still were obtained by using either rubber tyres or pneumatics upon the drivers, but then the cost began to enter into the matter, and was a very serious factor. He believed the Hon. C. S. Rolls, who drove one of the largest and fastest pleasure cars in this country, had calculated the cost of his pneumatic tyres at about 2*d.* a mile, which was something like 200 per cent. more than the cost of the oil used in running the car. It would be seen, therefore, that the question of the interception of vibration by pneumatic tyres, or by some other means, was one well worthy of attention, and if means could be devised of obtaining approximately the same results, which were obtained with a pneumatic tyre as a vibration interceptor, without using rubber and such easily destructible material as canvas, then a very great point would have been gained.

Another point which engineers could give their attention to, and which he should strongly advise them to give attention to first, was the transmission gear. There could be no doubt that in many cars a large proportion of power developed at the engine was taken up in the transmission gear before it reached the wheels, and to those engineers who were considering the question of motor cars, or were about to consider it, he would advise them to give their attention more to the improvement of the transmission gear than to the development of anything new in the shape of motors. He referred particularly to those who were thinking of dealing with the oil motor, with which he was best acquainted. Hundreds of

(Mr. Henry Sturmey.)

engineers had thought that because they could build a gas engine it was easy enough to build an oil engine, which should run satisfactorily on a car, and 90 per cent. of them had found that they could not. For instance, he had met a gentleman, well-known probably to some of their American friends, Mr. C. J. Field, the President of the American Automobile Club, who had been to Paris to secure the rights of the De Dion motor for small cars, and had told the speaker that, like most other people, he had thought it was easy enough to build an oil motor; but after expending 5,000 dollars he had come to the conclusion that it would pay far better to go and get something already proved, instead of trying to do what other people had done before him. Another thing in oil cars which engineers might give attention to was the question of the circulation of the water for cooling. Three or four years ago he used to carry upon his car as much as 15 gallons of water for the sole purpose of cooling the engines. Now by the use of radiating tubes the amount of water had been reduced in some cases to as little as four gallons, but in most cases circulating pumps were still used; and those who had followed the 1,000 Miles Trial would be aware that the failure of the circulating pump was one of the chief causes of trouble in most of the cars. Therefore he thought that the development of a system of natural circulation would finally work its way to the front. It had been done successfully on both small and large cars, and that was a line in the direction of which he thought investigation might very well be carried on.

Mr. GUS. C. HENNING said that, as an American Member of the Institution, he desired to accept the challenge made by Mr. Bryan Donkin (page 270), who suggested that American engineers might develop an automatic recorder for indicating what is now considered almost impossible, the relative amount of noise made by various motors, and to offer remedies for obviating the noise. He thought Mr. Donkin perhaps believed that Americans were very noisy themselves and therefore familiar with noise, as were some of their European friends. There were two ways of dealing with noise in America; one was to shut it up. This had been done recently in one case very effectively. The other way was the use of a proper design, and his experience in Paris quite recently within the last month in his own country, and in Great Britain, showed him that the average amount of noise produced was much less in American motors than in any that he had seen in Europe. The greatest amount of noise produced by motors in America was due to the puffing of naphtha oil engines. The steam motor, especially that mentioned by Mr. Donkin, the "Stanley," was not only a very pretty machine, but almost noiseless. He did not know what Professor Hele-Shaw had found out from the long trip, the longest trip the "Stanley" had ever made, under the most difficult circumstances, but in America that motor had operated practically noiselessly. At least he found it noiseless from his own observation on the very fine roads in and about New York City. The other way to avoid noise was one that must be left to the engineer. In examining motors he had always found that very little attention was paid to the elasticity of materials, and as long as the gear was very elastic and mounted on a relatively long elastic shaft in which the bearings were not close up to the gear, noise could not be avoided, and the faster a motor was run the greater the noise would be. The shaft with the wheel mounted on it would be practically like a vibrating disc—the string of a piano; and the enormous number of impacts on the teeth, even if the gear had been most accurately cut, would produce a noise that could not be stopped by anything. He wished to relate something that occurred in 1888 at Manchester, where a friend of his, the owner of one of the largest works there, kindly showed him his shops, speaking with pride about his noiseless gears, to which he wished to call his particular attention. They were cast gears, trued up a little bit on a grinder to smooth off the roughness. In walking into the shop he had to get on tiptoe to shout some remark into his friend's ear. He would not mention names, but perhaps the members would recognise the works. He asked him something about the testing machine which he saw building in a particular room, but his friend replied, "Oh, I did not take you in here to show you my testing machine, but I wanted you to look at our noiseless gears." He looked around, and positively

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there was such a noise there that he could hardly hear what his friend said, so it gradually dawned upon him that the noiseless gears were the things that were making the noise in that shop. There were two or three pairs, driving shafts at right angles. He could not see the point, and his friend did not either.

With regard to the smokelessness of motors, there were two ways of preventing it. One was to have a properly designed, smokeless combustion chamber—and there were several in use now which were smokeless under all conditions—but as the Americans had been referred to he should like to offer two other remedies, namely, use the very best American oil, or what was much easier, buy some American anthracite and try it, to avoid smoke. The picture hanging in the Reading Room of the Institution showed New York taken by a photographic apparatus under the ordinary atmospheric conditions, with tens of thousands of engines running every day, and yet not a speck of smoke could be seen anywhere in the busiest part of New York City: nothing could be seen but steam. That picture showed the four giant stacks of the New York Steam Co., generating more than 56,000 horse-power at the time, without a trace of smoke. That was the result of using American anthracite coal, and if such coal were used in motors it would have a very great effect. Very little of it had to be used, as it gave such a great heat, and burned such a beautiful clean fire; it would remedy the difficulty of smoke most effectually.

He should like also to say a word about the steel road bed. He thought that that had been only an experimental affair; he did not know that it was seriously contemplated to cover the road beds of America with steel. But in the United States a great deal of experience had been obtained in handling heavy material, especially lumber out of the forests, which was taken through the marshes and over their rough country on what were called logging roads, which were nothing but roads of timber laid lengthwise like the railway stringers formerly used in this country, with ties at long intervals, and with a strip of iron laid longitudinally on top of the stringers. They answered very well, but that was slow transportation. Undoubtedly if such transportation could be provided where the roads were not quite as beautiful as they were in Great Britain or the Continent, it would add materially to the wearing qualities of the machines, which of course had resistances to overcome that no ordinary engine on rails had ever met with.

Mr. Henry Fowler said he had had during the past six months experience with a heavy motor lorry, and it was on that class of car and not a pleasure vehicle that he should like to speak. He thought it was generally realised that a heavy lorry must essentially be a steam vehicle, owing to the flexibility of steam. He had the pleasure during last summer of going out as an observer at the Automobile Club trials, on what was, he believed, the first oil-driven heavy lorry which had been in use in this country; and it was remarked throughout the whole of the trials that the great disadvantage was the very slow speed at which the hills had to be taken.

The question of the effect of motor cars on horses had been dealt with that morning, and he might say that with the heavy cars with which he had been associated—and he had run with many of them—there was practically speaking no trouble with horses, if attention was not called by the driver to the fact that there was a new apparatus on the road, to which the horse was supposed to take objection. He knew that in many cases it had been found that drivers had run to the horse's head, while the horse had been calmly proceeding along the road, and had jerked his head up, and in every possible way called the animal's attention to the fact that there was something on the road at which he ought to be frightened.

He would like also to call attention—more particularly Professor Hele-Shaw's attention, as he was associated with the Liverpool Self-Propelled Traffic Association—to the fact that the trials which they had made only extended over three or four days. It would be far more satisfactory if the cars could be taken and run for six months, because there were things which developed in the course of constant running that could not possibly be noted during the three or four days or week over which the trials were carried out. One hardly realised until one went on a motor—at least it was so on a heavy car—what

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very bad roads there were in some of our important towns. Doubtless many members knew the very bad piece of road which led from the yard in which the Liverpool Trials had been carried out to the main streets. But that was not a solitary example. It had been found that in several of the largest cities in the North the roads in the centre of the town were really a disgrace. With a slowly moving, horse-drawn traffic this was not realised so much as it was with heavy lorries, travelling at about 5 miles an hour. He thought it reflected the very greatest credit on many of the makers that they had had cars running in those towns for a considerable period. He was sure that any member who would travel a short distance on one, and see the vibration and shock to which the car was subjected, would quickly realise the fact he had been stating.

There was one difficulty to which he should like to refer, and that was the 3-ton tare, necessitating as it did the use of a very great deal of aluminium. Aluminium was probably a good material in its right place, but if it was to be put into parts subject to even small wear, or where it was subject to constant repetition of strain, it was unsatisfactory. He thought it would be found that, if the tare could be raised so as to exclude aluminium altogether, it would be a very great advantage to the industry. Another point was that the boilers should be as large as possible with heavy cars which had to be used on hills that were, comparatively speaking, steep. He had seen several types of cars which had had to stop for steam while going up a long continuous rise. This was only likely to occur in certain parts of the country, but it was in these very parts that the heavy motor lorry was of the greatest value. The pumps also which were supplied to several of the cars were too small to feed water into the boiler, even if the boiler were large enough, on a continuous hill. He thought that with present practice it was realised that gas coke, which was practically speaking smokeless, with a driver who would pay attention to his fire, had superseded all coal in this country. There was no trouble with steam showing, if the car was properly designed, and if the driver would take a little care, excepting on certain days in the winter, when it was looked upon as an occasional nuisance, and one therefore that the law did not affect. But in many cases the question of fire risk had not been thought out in the design, and there were warehouses and sheds of various descriptions in which a car, without some allowance made for fire prevention, would not be allowed to go. He knew that with coke there was practically speaking no fear of sparks, but under certain conditions, the using of a very fine coke, and with the driver putting his jet on, it was possible even for coke to throw out sparks from the chimney of a motor car.

He was glad to see in the Appendix III (page 235), which Mr. Lyster had contributed to the Paper, that he had overcome the difficulty of travelling in snow, because he believed that for heavy motor traffic it was essential that it should be regular, and of course it was very necessary, if horses were to be dispensed with, to be able to travel in snow. If Mr. Lyster was present, or if Professor Hele-Shaw was able to reply, he thought he would be conferring a very great benefit on users of motors, if it could be stated how that was overcome. He knew that by neglecting to follow out the letter of the law and putting a number of shoes on, it was possible to run even in a considerable depth of snow, but Mr. Lyster no doubt had a little difficulty in getting out of the yards in which he had to run, and the main streets of Liverpool were so well swept and dealt with during snowy weather, that practically speaking they were pretty free from snow soon after a fall.

M. Edouard Sauvage said that, with regard to the danger arising from horses getting frightened by motor cars, he might be allowed to add a few words from his own experience, as he lived in a country where motor cars were very much used. It was a fact which must not be overlooked, that in a very short time horses, or at least a great number of horses, became quite accustomed to the cars, just as they became accustomed to railway trains, electric trams, and bicycles. Of course there were special cases, and there might be one or two shy horses which could not stand the sight or noise or smell of a motor car, and then such horses caused trouble to their drivers. Speaking of the streets of Paris, he confessed that, even in the middle of the city, motor cars were often to be seen

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going at a fearfully dangerous and ridiculous speed, but it happened very seldom that horses noticed it at all. Speaking of the careless driving of motor cars, he thought some inconvenience might arise, not to the horses, but to the motor car itself. In fact, if the motor car had developed so much in France, he thought one of the important causes was that the motor traffic was entirely free from any troublesome regulations and any undue official interference; and the result was a splendid development of this industry. When motor carriages were seen tearing about at such great rates of speed, some of the people began to be frightened, and objected to it, and wanted some strict regulations to be made. All sensible automobile car owners tried to discourage such excessive speed, clearly seeing that, if strict regulations were enforced, great trouble would arise. What was required was to have people driving their cars properly, but with no special rules as to speed not exceeding such and such a rate, which would be much too low in some cases, and much too high in other cases.

Mr. JOHN I. THORNYCROFT, Member of Council, said he thought the subject before the Institution was one which really demanded very careful consideration. The remarks of previous speakers had been upon points which were all very important, but most of all was that of restrictive legislation. It had been remarked by Mr. Fowler (page 280) that in order to comply with the law, aluminium had to be used in a considerable quantity; and he also stated that in order to make a car climb a hill successfully the boiler must be made larger. Now, having exhausted all the saving made by the use of aluminium and by making the boiler larger, one was still left within the grip of the law, and he really did not see a way out. As the law now stood, the industry was in danger of being crippled. The suggestion of a call upon the Institution to exert itself to preserve the industry from restrictive legislation was a proper call, and was one which he was glad to hear was answered by applause, as though the members felt it was their duty to do something in that direction. With regard to horses that of course was rather a difficult and delicate subject, but he did feel it was incumbent upon all drivers to take the utmost care and consideration. He was exceedingly glad to know that at the royal stables some care was being taken to educate the horses. M. Sauvage had stated (page 281) that horses soon learnt all about motor cars and took no notice, and he believed that was a fact. The real trouble with horses was not in the crowded towns but in the country. Horses in towns had become better educated, but if a motor car was going along a country road it attracted more attention. With regard to the details of the Paper, he thought he might say that Professor Hele-Shaw had dealt so amply with the subject, that he did not see what he could add of advantage. No doubt the vibration due to bad roads was exceedingly injurious, and it would be a great advantage if roads, especially in towns where heavy loads were carried, could be better attended to. But still there was this advantage, that if the motor-car builder had to contend with great difficulties, he would be forced to exert himself and overcome them, and having got a really good car in that way, it would appear to be all the better when the roads improved. He thought that was really the best way to view the problem.

Mr. W. WORBY BEAUMONT thought the Institution was indebted to Professor Hele-Shaw for having brought before it what he ventured to think was one of the most important branches of mechanical engineering. It had been, of course, in one Paper altogether impossible to deal in detail with the very big field that had been opened up, not only in the building of the heavier vehicles, but in the still larger field of the building of lighter vehicles, vehicles which had already exceeded the speed of most trains, and had more than doubled the speed at which ordinary people, living a little distance from town, could go from their houses to their offices. Mr. Thornycroft (page 283) had mentioned one question with regard to the vehicles on roads, and had advised them to make a good vehicle and then get good roads. He himself thought that one of the most important points in connection with the subject was the road question, and it was necessary to do for the ordinary roads what was done for locomotives, namely, first make a good road for them to run upon. In this country there were a great many miles of very

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good roads, but there was no reason why anyone should put up any longer with the enormous waste of money and of time that resulted from the habit of always climbing over every bit of obstruction in the form of hills that Nature happened to leave in the way. There was no reason why people should not now ask for a little more help towards the improvement of many of the roads by slight divergencies, by cutting off the tops of those very expensive hills, and by a better maintenance of the roads that were in use. To a great extent the subject might be reduced at present to one of maintenance. All over the country, in the largest towns as well, roads could be seen constructed at great cost; and then as soon as they were finished they were left with practically no maintenance, and went from bad to worse, until it cost the nine stitches instead of the one which proper maintenance would have found sufficient to keep them in order for a great length of time. He said great cost in this connection, because bad roads prevented the adoption of lighter vehicles for heavy work, and larger boilers were wanted. In many places people, who were sending out a load of perhaps not more than a ton or so, had to send two horses, because out of the whole of the distance which had to be traversed there was perhaps a fraction of anything between one-tenth and one-twentieth which needed two horses. Thus because of some bit of a hill the cost per ton carried was often doubled. There was no reason why, simply because the roads had been always so, people should any longer, if importance was attached to cheap transit, put up with the conditions that now obtained.

With regard to the cost of transit, the author had given some figures, showing that the cost per ton per mile was, over certain distances, less than the cost by railway for carrying given loads. Those figures were in themselves of considerable importance and value; but it should be noticed that the real cost of conducting a traffic in heavy materials depended not simply upon what was found to be the cost per ton per mile on experimental runs. A vehicle, for instance, which might profitably be used to conduct a service for a 25-mile run out and back would be non-paying for a distance of 40 miles, with the speeds that were at present permitted; and not only the speeds that were at present permitted, but which practice showed to be as high as could economically be followed. The wear and tear of vehicles with a load beyond the speeds permitted became so great, that the maintenance question brought up the cost from what it might seem to be per mile on experimental runs to something very considerably higher, and in some cases to such a high cost that the business became an impossible one. The cost of loading and unloading was a matter which had to be considered in connection with the goods transit operation, when trying to arrive at some estimate as to the probable value of any such service. He had a few figures by way of illustration of that point taken from an investigation and report he had had to make with regard to two different intended services, intended that was, if it could be proved that the cost would be one that invited the construction of works at either one or other of two different places at different distances from London. The figures included the cost of a given quantity of material carried at these distances in various ways, that was to say, taken to the station by the owners of the material, and taken from the station by the owners of the material at the other end; or taken and delivered by the railway company; or taken by ordinary goods trains or by trucks specially built to run on some of the fast trains. It included the cost of doing the work by either three-ton vehicles, or by a larger number of vehicles capable of taking at a higher speed one-ton loads, and going not only at the higher speed with a load, but when empty returning at much higher speeds. These figures showed that the least expensive way of doing the work over a 50-mile course was by means of the heavier vehicles. As compared with the railway the total cost by either of those means for the 50 miles came out at not very much more—even under very adverse circumstances—than half of what the railway companies would charge. But the cost of doing the same work by means of horses, taking into consideration everything that might be imposed by the manufacturing and the commercial exigencies of the business, had come out to only about 15 per cent. more than what appeared to be the cost by motor vehicles. On the other hand, when the question was one of the dealing with distances which enabled the motor vehicles to work

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under the best conditions, as to the service of the men, the suitable number of hours for their working, and suitable speeds, then it was found that the motor vehicle came out very much less in cost for the work than if it was done with horses. For other distances the railway transport was cheapest.

There was one matter of construction which had been the subject of the greatest trouble and the greatest amount of scheming, though it had now been practically settled, and that was the method of preparing the oil or petrol, that is, the mineral spirit which was used in about 99 per cent. of all the vehicles running, for mixture with the air, and its proper combustion. Professor Hele-Shaw had touched upon those matters without giving any information, and there were two or three expressions that might be somewhat misleading. The author referred to vaporising carburettors by which the spirit was so heated as to ensure its giving off a certain amount of vapour when a current of air was drawn through over it. In weather like that now being experienced there was very little necessity for heating; in fact, no heating was done by a very large proportion of those carburettors, which were of the spray-making induction type. The carburettor, properly so called, was a vessel in which the mineral spirit was carried in such a way that it was able to present a very large surface film to incoming air, which would rapidly take up the full quantity that it was possible for it to vaporise and carry. The best of those carburettors necessarily were those that presented the largest amount of surface to the air passing through at a very great speed. They, however, were of large size, and occupied considerable space, and there were certain difficulties about them. Very frequently with most of them the spirit vaporised in such a way as to give off the lighter parts first, and leave in the bottom of the accumulator vessel a certain quantity of that which was heavier, and then a difficulty was found next day, or when it was wished to start again, in getting the air carburetted quickly enough, with the result that many people were much troubled in getting their motors to start. The spray carburettor, made to some extent on the line of the scent-spray, was not, practically speaking, in the sense of the original one a carburettor at all. It was really a mist-making apparatus. The fact that no vapour was obtained was of extremely little importance, inasmuch as the mist would ignite much more readily than even the vapour. The different forms of spray carburettors now had a feed apparatus, which was simply a small vessel carrying a float maintained at a certain height, on the same principle as an ordinary ball valve. It had to be made so that it could not dance under the circumstances of the running of the vehicles, which he supposed had more to contend with in the way of vibration shocks and jolting and extremely heavy work than anything else that was made.

With regard to governors, many vehicles ran governed for a part of the time, but some makers attached an accelerator, which was a piece of cord or apparatus, that released the governor. The result was that when a man found that dawdling along at 15 miles an hour was no longer favourable, he put on the accelerator, which let the engines that ought to run at about 750 revolutions a minute, run at 1,500 or 1,600 revolutions a minute. That might seem rather a dangerous proceeding, judging from past experience with steam engines and with gas engines, but it was a fact that, in spite of the very high speeds at which motors ran, the motors themselves might be said to give less trouble than any other part of the vehicle. Even when they were turned over, the motor continued working, wherever the vehicle might happen to be.

It was mentioned in the Paper (page 209) that certain vehicles used a very small amount of cooling water. Coolers were being used now with a natural circulation, by means of which very little water was required for a whole day's run, but there were some vehicles running of which the makers said that no water was used, as the cooling was done by means of a fan. In one case the maker stated that he only used 2½ ounces of water on a 50-mile run. Examination of the results of the running of that vehicle showed that the cooling was done at the cost of something like 20 per cent. of what might have been the mechanical efficiency of the whole vehicle. So that when a vehicle was said to use only very little water, it should be carefully noticed by what means that result was obtained.

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With regard to balancing, he would like to say that it was not a question of simply balancing the engines, because many of them were very nearly balanced. The vibration that was seen in motor cars was the result of the infrequent ignition when the car was standing and the engine was running light, and it would be the same if that engine were absolutely perfect in balance. It was the unbalanced torque when suddenly and occasionally exerted which caused vibration. If the crank-shaft of the engine were held, the engine would go round the crank-shaft instead of twisting the crank-shaft, and that was what the engine tried to do at every ignition. No matter how much the engine was balanced, unless frequent impulses could be obtained, which might be done in several ways, the vibration of the cars, while the car was standing, would continue. All that disappeared, of course, when the car was running.

Mr. Sydney F. Walker thought that nobody contested the fact that the autocar of the future would be electrically driven, and therefore as an electrical engineer he was more interested in that side of the question than anything else. At present oil and anthracite coal reigned supreme, but as an engineer he begged to point out that the oil and the anthracite coal were burned in the wrong places. They were used under the most uneconomical and wasteful conditions when they were burned to drive the small motors, which motor-car builders were obliged to use in their cars. Whether the motors were large or small, it was necessary to waste a considerable amount of energy in cooling and all sorts of other things, and to have all kinds of what he ventured to call " gimcrack " apparatus. An electrical car practically dispensed with all that, and gave a most perfect method of control. The electric motor was the most perfect governor that the ingenuity of man ever devised. Professor Hele-Shaw had pointed out that there was one drawback: at the present time an electric accumulator could only be put on a car to run for 40 miles. A motor car was worked under the worst possible conditions for an electric accumulator. Where there was plenty of space and plenty of weight—space for the plates, weight for the plates, and all the rest, and convenience for testing—the accumulator was a most economical and useful apparatus; but on a motor car space was confined as well as weight, and the accumulator was constantly jogged, and the rate of jogging was constantly varying, the consequence being that the plates were continually wearing out. He had heard that in France they had already got as far as a 156 miles run, but in this country they had not got beyond 40. The manufacturer said 60, but he would rather they were not taken at more than 40, and he thought the manufacturer was wise. He ventured to think that the outcome of the accumulator was that the lead plate would have to go. A lead plate only performed the same function that a carbon plate did in a great many other batteries; it collected the current from the oxide or lead, or whatever it might be. If the current could be obtained from the liquid or in any other way without the lead plate, an accumulator would be much more useful. Lead was a heavy and a flexible material. The suggestion he ventured to make of the lines upon which the autocar accumulator of the future would go would be that the lead oxide and the finely divided lead would be built up upon a light framework of some other metal. He was aware that he would be told he had thus a galvanic battery, but there was already a galvanic battery, and the most powerful battery that could be obtained, in the lead and the lead oxide. There was also a galvanic battery on the negative plate, and he thought when the subject was worked out there would be less trouble with a light framework of platinum or aluminium, or something like that, with the oxide and the finely divided lead plates on the framework than there was now. There were difficulties ahead, of course; it was a case for the inventor, and a case for spending thousands of pounds. But when that was done, an accumulator would be produced which would be far beyond oil, anthracite, or anything else. [*See also page* 316.]

Mr. M. Holroyd Smith said the Institution was one of Mechanical Engineers, and being a mechanical engineer himself he should like to take the opportunity, both for his own benefit and the benefit of other people who were working and struggling on the

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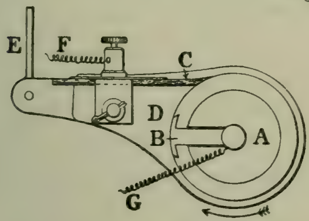
question of autocars, to get some precise, useful, and definite information from those gentlemen who had spent so much time in accumulating subject-matter for Papers. It had no doubt been very interesting for the Institution, from a social point of view, to hear the questions of roads and legislation discussed, but such questions afforded no help on the details it was the special business of the mechanical engineer to deal with. He was afraid that time was too brief to go through the Paper in the detailed way he should like to have done, and he should therefore confine himself to asking a few short and pertinent questions, hoping to elicit certain information that might be of benefit. In the Paper the author referred to a geometrical principle of steering cars, and there was an illustration, Plate 32, of a method now in general use. He wanted first of all to ask Professor Hele-Shaw why it was that some arrangement was not made whereby efficiency in back steering could not be obtained as in forward steering. It was too long a matter to enter into an academical discussion upon, but those who had tried the method shown in the diagram, knew that, though the steering was very good when going forward, it was altogether wrong when going backward, and it had consequently become necessary to adopt the wheel steerer in order to get control over the guidance of the motor when running backward. It was, as he said, an academic question, and he did not care to enter into it fully, except to ask Professor Hele-Shaw if he would kindly make an addendum to his Paper, and give the Institution the full particulars of the geometrical steering gear of Mr. Davis that he had referred to as answering every requirement (page 201). A steering gear to answer all the requirements must be able to steer a car backward as well as forward with equal efficiency.

The next point he wished to refer to was the reference made to heavy oil engines. The author said (page 203), " In connection with this matter some recent experiments by Mr. Henry Barcroft of Newry, who has succeeded in maintaining constant mixture and compression under varying load, promise well for the future." He, the speaker, had had the privilege of seeing a model of that engine of Mr. Barcroft's (page 302), and it had a very praiseworthy aim.

The object of the engine was to have a varying power by giving a varying length of stroke. Many people had attempted things of that kind, but Mr. Barcroft realised the difficulty that, as soon as one began to vary the stroke, one began at once to vary the ratio of clearance and working space in the cylinder. It was easy to construct an engine giving a varying length of stroke, but it was a difficult task at the same time to maintain the correct relation of clearance space and length of stroke, and so secure a uniform compression under a varying length of stroke. The details of such an engine would be an addition to the mechanical knowledge of the Institution, and therefore he asked Professor Hele-Shaw if possible to give that information. Reference was made further on in the Paper to electric ignition for motor cars (page 206). Those Members who had had real experience of the matter—he did not mean the experience which simply came from riding on somebody else's car, and being talked to about it, but the real experience of thrashing the thing out in one's own head, and then in the workshop trying to put the thing together—must know that with electric ignition there arose a difficulty, the difficulty of always making and breaking the contact at the proper time. The usual plan was simply to have a fibre disc fastened on to the cam-shafts, Fig. 60, and in that fibre disc insert a metallic portion, supposed to be connected with the battery, but frequently in a manner doubtful in design and workmanship; then to have a brush or equivalent device which, being a spring itself or by means of springs, pressed upon the periphery of the disc, and when the metallic portion passed under the brush, contact was made, and a spark was produced in the cylinder.

Fig. 60.



A.	Revolving fibre Disc.
B.	Metal Contact.
C.	Contact Brush on insulated Arm.
D.	Insulating Arm.
E.	Rod for altering position of C.
F G.	Wires conveying electric current.

(Mr. M. Holroyd Smith.)

Timing was adjusted by mounting the brushes on a rocking arm in a manner similar to that adopted for dynamos. The arrangement was all very nice and very pretty in the workshop, but the difficulty was that in all oil engines there was not only the oil or spirit which was being used for producing the power, but a considerable amount of oil was used for lubrication, and that penetrated where it was not wanted, and had a great proclivity for getting all round the fibre disc, and so saturating the brush with oil that, when the contact-making segment came under it, there was either no contact at all, or indifferent contact, or some delay in the contact. Another objection to this method, which was in common use, was that the brush had to press hard in order to make good contact, and that pressure was maintained all the time, thus creating frictional resistance, though only really required whilst the metallic segment was passing under the brush. When an excrescence was used on a disc to make contact with an excrescence on the end of a spring as it passed, then the vibration set up in the spring would affect the timing of the spark. He mentioned these difficulties because there had been several suggestions that morning as to what engineers should turn their attention, and he thought they required something better than at present existed for electric ignition. Some device which would make the moment of contact for the sparking instant accurate, and always reliable at the precise moment it was wished for.

With reference to the balancing of a motor engine, the author said that in order to understand the action, it must be remembered that two cranks were disconnected, and the two fly-wheels moved in opposite directions, and that of course with only a vertical cylinder engine the piston was not balanced. He, the speaker, was rather surprised to find such a statement, because he would venture to remind the author of the little model he exhibited to the Institution at the Birmingham Meeting,* where with a single cylinder there was an absolute balance of the piston.

The questions of detail were so numerous that it was impossible to deal with anything like all of them, and he would therefore turn to another question which he thought might form a distinct Paper, namely, the question of wheels. Professor Hele-Shaw dealt very well with the question of wheels, although he thought he should disagree with some of his premises if it came to argument on the point. The words, "The problem of spring wheels" were used in the Paper, and the present solution or the tendency towards solution was relying entirely upon the tyre at the periphery of the wheel; and pneumatic tyres, indiarubber tyres, and other various kinds of tyres had been used. The members would all know quite well that when traction engines first came forward in years gone by, a great deal of thought was given to the question of spring wheels properly so-called—not merely elastic tyres to wheels. He thought he had searched, perhaps not all the records on that subject, but quite as much as his patience had enabled him to do, and he had found that the majority of people who had worked on the question of spring wheels hardly seemed to have formulated to themselves what were the theoretical requirements of the spring wheel. After all they were exceedingly simple to formulate, though difficult to carry out. What was wanted in spring wheels was a perfect radial movement between the hub and the tyre, and no other movement. The wheel that in recent years approached close to that requirement was one known as the Deburgo wheel, in which the hub was made to move in a slide, and that slide was made to move in another slide at right angles thereto. Most people were very apt to forget the things that were drummed into them when they were boys, and most of the designers of spring wheels had apparently forgotten that a circular movement was a movement compounded of two movements at right angles one to the other. By the Deburgo hub the object of which he spoke was obtained, but it was obtained at mechanical inefficiency and mechanical complication, and he would endeavour to show the Members how the same thing could be obtained without the mechanical detriment of the slides—namely, two movements, one at right angles to the other, which would give perfect radial movement, and no other movement. Going back to one of their fathers in engineering, whose name ought always to be spoken with great reverence and respect, Watt of the steam-engine,

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* Proceedings 1897, page 351, and Plate 77.

(Mr. M. Holroyd Smith.)

it would be found that he invented the parallel movement for guiding the connecting-rods from the piston-rod to the beam. The combination was well known to engineers, and though it did not give an absolutely true rectilinear movement, it was sufficiently so for practical purposes, and had been good enough for the old beam engine that had worked year in and year out for more than two generations. Now if the anchorage points of one set of parallel rods were attached to a frame linking them together, and this frame by a duplicate set of parallel rods is anchored at right angles to the first, a compound parallel movement would be obtained, which would give a perfect radial movement. The anchorage link would prevent torsional movement, and the radial movement would be restrained by springs. [Described in greater detail in pages 314–316.]

Mr. ARTHUR VENTRIS said he was present at the meeting to listen and not to speak, and he had to thank the Institution for allowing him to hear the Paper and the discussion. He was, however, only the user of a motor in one sense. He was surveyor to a local authority, the Strand District Board of Works, who possessed a motor van, and whose district was situated in a very central part of London. He had thus had experience of one of Messrs. Thornycroft's heavy motors for about six months, in a district which was very crowded, and where the streets were comparatively narrow. He might say that he had the satisfaction of reporting to the Institution that there had been no accident, no nuisance, and no complaint of any kind with regard to its use.

Mr. T. W. E. HIGGENS said he was in very much the same position as Mr. Ventris, as he had used a motor car successfully for a few months. He wished to impress very strongly on the meeting the remarks contained in the first part of the Paper concerning road surface. He found with the use of his motor car that it was entirely a matter of road surface, and that a rough road made the traction most difficult. London motor car owners were in an awkward position: the County Council desired to put down tramways in the main streets, and spoil all the road surface that Londoners had already laid; if this was done, motor cars would be at a great disadvantage. It was necessary for mechanical engineers to impress on the road authorities that to work a motor car efficiently, a perfectly smooth road surface was required, and that was the point he wished to urge upon the Members—namely, the efficiency of motor cars was largely a matter of road surface.

Mr. **HENRY DAVEY**, Member of Council, said he should not trouble the meeting with any criticisms on mechanical details, and he only rose to correct what he thought was a misapprehension existing in the minds of one or two of the speakers when alluding to the forcible remarks which were made by Mr. Harry Jones (page 272). As a mechanical engineer, he, the speaker, had great sympathy with the motor car, and he had also for horses. Mr. Sturmey (page 272) said that there was no prescriptive right to the rule of the road attached to a vehicle drawn by horses. That was an error, and he thought in a Law Court he would find that it was so. A prescriptive right was a right which was obtained entirely by time. He contended that the rule of the road was as important to the driver of the motor car as it was to the driver of a horse vehicle, and that was a point which ought not to be lost sight of.

Mr. **HENRY MCLAREN** wished to make a remark from the standpoint of a traction-engine builder. He had had thirty years' experience of road work, and during the last fifteen years in high-speed traction-engines, which was very similar work to that which motor wagons were expected to do. There were one or two points to which he should like to call attention with regard to the steering gear shown on Plate 32. In the Ackermann system of steering gear the wagon was supported at the four corners, and the springs must allow for the inequalities of the surface of the road; consequently the framing was subjected to great twisting strains, and could not be expected to last long. The traction-engine was supported on three points, like a three-legged stool; it was always standing easy, no matter what the ground was like. There was generally a dip at the

(Mr. Henry McLaren.)

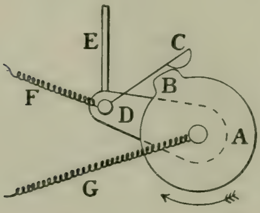
side of a road; a wagon supported on four points, in turning out of a road, dropped the near wheel into the dip first, and that strained the frame. The question of weight was a practical point. His firm were asked by a customer when the Act was passed to make him a motor wagon. They made a design, and found that it could not be done on three tons, and they declined the order. He thought if the Institution could do anything to increase the weight limit to four tons, it would be doing a very great service to all users and makers of motor wagons. There was one motor wagon that Professor Hele-Shaw had not shown. In Leeds and district the most successful motor wagon for heavy work was the "Mann" motor. He was not in any way connected with the firm, but he wished to show in what an ingenious way the Act had been met by that car. The Act said that with an engine of three tons weight a wagon might be pulled weighing one ton. If a load was put on to this wagon in the ordinary way, there was not adhesion enough in the three-ton engine to pull it. In the "Mann" car two wheels were placed on the wagon, and these straddled the wheels of the engine. The two outside wheels were attached to the wagon body, and when they wanted to weigh, they wheeled the wagon on to the weighing machine, and it weighed one ton, and then they ran the engine portion on, and that weighed three tons. But when it was working, bolts were slipped through the bosses of the engine and wagon wheels to couple them, making really a four-ton engine and wagon combined. That had been held to be quite legal. The company were now building large new works to meet the great demand they had for these wagons, and that would be done by all makers if they could get a four-tons limit instead of three, which was a most important point indeed.

The tyres were another very important point in motor wagons. Fifteen years ago he was over in France, and was working a Fourgon post there with high-speed traction-engines. He had to do continuously with these engines about a thousand miles every fortnight, and that was kept up for eighteen months; of course in such a test the weak parts in wheels, &c., were very likely to be found out—and they were. It was well known that when a tyre became thin it stretched off, and the tyres of those traction-engines did this. Then they were put on in sections of two or three feet in length, but the same thing happened. At the finish they were put on in plates something like the cross bars of traction-engine wheels, plates 6 inches long, and the whole width of the wheel. The plates were made 1½ inches thick, and they stood an enormous wear. A ¼-inch space was left between each plate, which very soon filled up with dirt and worked smooth. They had wheels on high-speed engines that had run over 60,000 miles, and were still in perfect order. All the leading makers of traction-engines knew how to make wheels which could stand great wear and tear. He had a large number of engines in New Zealand working at high speed, carting wool, &c., and nothing was known about difficulties of tyres on the wheels. It was quite wrong for Mr. Holroyd Smith to say that the spring wheels would not work. His firm had made over 100 sets, and many of them were working to-day. He had tried the same thing that Mr. Holroyd Smith had described (see Fig. 63, page 315); it worked, but it would not stand the wear and tear that traction-engine customers required. He had had a letter from a customer of his who had had an engine twenty years. He was boring the cylinder out, and found a blow hole in it, and asked his firm whether they would not replace it, seeing that it was defective material. That would give the Members an idea of what makers of traction-engines had to contend with. Motor car builders make motor cars to run three or four years, but traction engine makers had to make their engines to run half a life-time.

The CHAIRMAN, Mr. Edward P. Martin, Vice-President, said the discussion had been a most interesting one, and he was sorry to stop it, as the time was now coming to an end, and it was necessary to call upon Professor Hele-Shaw to respond as far as possible to the various points that had been raised. He might mention that the Secretary would be pleased to receive written communications dealing with the Paper.

Professor HELE-SHAW said, as the hour was so late and there were other Papers on the agenda, he felt it was impossible to answer or to attempt to answer all the numerous points that had been raised, and do them justice. Whilst asking permission, as a mark of respect to those gentlemen who had spoken, to answer their remarks later and in writing, there were just a few matters with which he fancied the members would rather like him to deal as rapidly as possible. There was first the question of the possible burning of a car, of which unfortunately more than one instance could be cited. He might point out that the burning of the car itself was comparatively a trifle, but the burning of the owner was a very serious matter indeed. Now petrol or benzine, the spirit generally used for light motor vehicles, flashed at, or even below, the ordinary temperature. Hence supposing a car turned over, a thing which had happened to himself, if at the same time the petrol tank burst so as to saturate the occupants, a terrible accident was possible or even probable when tube ignition with a red hot platinum tube was the system of ignition employed. From experiments he had made he believed it to be almost impossible to extinguish the flames by any means likely to be at hand. This was one of the reasons which led him to adopt and advocate electrical ignition, which, as far as he could see, entirely obviated the danger from such a cause. This question of electrical ignition led him to reply to an objection which had been raised by Mr. Holroyd Smith (page 291). Mr. Holroyd Smith had drawn a diagram of a method of making electrical contact, Fig. 60, which was not adopted on any motor cars with which he (the speaker) happened to be familiar, and which certainly seemed open to the objection stated, namely, of being liable to "miss fire."

Fig. 61.



A.	Revolving metal Cam.
B.	Projecting part of Cam.
C.	Contact piece struck at each rev. of A.
D.	Insulating Arm.
E.	Rod for altering position of C.
F G.	Wires conveying electric current.

Fig. 61 showed the kind of contact-maker used on his own car. It would be obvious that with this arrangement the blow struck at each revolution by B upon C would wipe off the oil or grease and ensure electric contact, while the spring by which C was attached to D would retain B and C in contact for a small part of the revolution.

Mr. HOLROYD SMITH said there were some made in that way, but more in the way shown in Fig. 60. He had had them in use.

Professor HELE-SHAW thought they were obsolete now.

Mr. HOLROYD SMITH said the latest car direct from France had it.

Professor HELE-SHAW thought if it was not obsolete it ought to be. By means of the rod E the contact could be advanced or retarded, and this afforded a method of governing the speed, which was of special importance with small motor cars or voiturettes, which had no regular governor. The arrangement enabled the contact piece C to be either pushed forwards or backwards. If the contact-maker was pushed forward the ignition was early, if pushed backwards the ignition was late, and there was just sufficient force in the explosion to carry the engine over the end of its stroke, and keep it just running when the car was standing, thus doing away with the vibration, to which ladies in particular objected so much. He thought that for small motor cars this particular difficulty had thus been to a great extent removed. He should be happy to communicate details of the arrangement for dealing with snow, which, together with bad roads—not permanently bad roads, but the soft and greasy state of roads in continuous bad weather—was one of the most serious obstacles to the general introduction of heavy motor vehicles. He should be very pleased to try and show that the question might be met by a temporary attachment to the wheels. In dry weather a hard wheel which was suitable for the purpose could be used, and in wet weather a temporary broad tyre of wood could be attached which would not be destroyed as long as the road

(Professor Hele-Shaw.)

was soft and which would give a wider surface to run upon. That, he thought, was the direction in which this particular difficulty would be met. The arrangement could be carried in the car or attached in the morning, when the weather was sufficiently bad to justify it.

After all that had been said, he hoped the Institution would take a part with the Automobile Club, the Liverpool Self-Propelled Traffic Association, and other bodies, in trying to raise the legal tare. He might point out that the law did not effect the object which it had in view. It only increased the cost of a car by the necessity of employing aluminium and other expensive appliances, and tempted makers to under-power their motor wagons. The car was made to carry a load which was many times greater than the tare limit, and makers were putting a total load on the four wheels, which he believed was in excess of anything that was contemplated. If there were some restriction to the absolute load carried on four wheels, that surely would meet the object of the Act better than the indirect and ineffective way of trying to keep down the tare weight of the unloaded vehicle to three tons. This after all he did not believe was done in a single case. He knew of a motor car where in order to pass the inspector everything was taken off, including the fire doors, safety-valve, and other attachments, and when the inspector good naturedly went away these were all put back in order that the vehicle might be removed from the weighing scales. That inspector was a conscientious man, and would do his duty, but he evidently had some human feelings left.

He would try and write an answer to the other questions that had been raised, and hoped to be allowed to have something to say about the question of cost. Mr. Shrapnell Smith had assisted him in working out the figures on which the data were prepared, and the upper part of Fig. 53, page 224, was a further continuation of the curve above one day's run; because of course if a car was put up and stabled it added to the cost, and became more expensive. But even then he believed it could be shown that up to 100 miles, at the present railway rates, it was possible to obtain economy with it. It was proposed to have in Liverpool in the spring a new series of trials. He quite agreed that such trials would not prove everything, but they could prove a great deal, if properly conducted for—say a week. Mr. Thornycroft, he was sure, would be able to say that they proved of practical value, at any rate in one way, for he had had the courage to take his car after the first trial, and absolutely scrap it, and start again and build one of fresh design. He did not get the £100 first prize of the first year, but in the next year as a result of his enterprising efforts he took the two gold medals that were offered, partly in consequence of the lessons he had learned from the severe trials to which the first had been exposed. Next year it was proposed not merely to carry bags of gravel round the neighbourhood, a very interesting performance, and much admired by the agricultural labourers of the district, but to make a departure, for which Mr. Shrapnell Smith's enterprising mind was responsible. He had obtained a promise from shipowners to supply cargoes for a week's trial, which were to be taken and delivered in a business manner on business terms at warehouses in Manchester, going by Warrington, and returning by Bolton, taking in the populous and manufacturing parts of Manchester. In the next two days' trials the cars would be run to Blackburn via Chorley, and return via Preston. Those were trials which he hoped would enable him to bring before the Institution some facts which would be useful. Hitherto the trials had been favoured with very fine weather, and he hoped in the interests of practical results there would be at any rate some bad weather with variations in the state of the roads, even if the judges and spectators suffered from it. He was pleased Mr. McLaren has spoken as he had done. Probably the makers of traction-engines knew really more about the subject of road locomotion than any of the builders of motor vehicles, except possibly men like Mr. Thornycroft, who came to the subject from another wide field of experience. From what Mr. McLaren (page 297) had said, it was clear that if the same demands for motor wagons were to be made as by those who bought traction-engines, all he could say was that he was extremely sorry for those who made such wagons in the first few years of their experience.

The CHAIRMAN was sure the members would all agree with him that Professor Hele-Shaw had brought a most interesting subject before the Institution, and that he was deserving of a hearty vote of thanks, which he had great pleasure in formally putting to the meeting.

The motion was carried with acclamation.

Communications.

Mr. HENRY BARCROFT wrote that he had observed in the report of the Meeting in London that Professor Hele-Shaw had referred to experiments* which the writer had made for the purpose of overcoming the difficulty which has existed in the inability to obtain a uniform compression in explosive engines, if the stroke were made variable. After the construction of several models, each of which marked a step in advance, he had been enabled to design an engine, which, as regards mechanical details, complied, in theory at least, with the necessities of the case. The stroke could be varied at pleasure, while the space for compression was also varied in the proportion required, that was to say, if it was desired to have a compression of 50 lbs. pressure, this could be obtained under all circumstances of variation of stroke. It still remained to be seen whether the details of the engine, as regards the explosive mixture and the timing of explosions, &c., could be satisfactorily accomplished.

Mr. JOHN BARR, of Messrs. Glenfield and Kennedy, Kilmarnock, sent a description of Mr. Brown's viagraph † for testing road surfaces. The viagraph consisted practically of a straight-edge applied continuously to the road surface along which it might be drawn, and conveying an apparatus for (1st) recording on paper a profile of the road surface, and (2nd) indicating a numerical index of the unevenness of the surface. These, taken together, gave quite a fair estimate of the condition of the road at the part tested.

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* Proceedings, April 1900, page 203.

† Proceedings, April 1900, page 248.

Fig. 54, Plate 38, gives a general view of the instrument, the frame of which is in form like a sled with straight runners. On this are mounted the working parts shown on Figs. 55 and 56. The lever T pivoted to the main frame at H carries on its free end a serrated wheel, which is shown at V. While the main frame, in being drawn along the road, preserves a sufficiently even line, the road wheel V rises and falls over all the unevenness of the surface, carrying with it the lever T, and thereby transmitting its movements by means of the link and lever S to the pencil P, which marks the full amplitude of these motions on the paper passing round the drum A. While the motion of the pencil takes place in a vertical direction, the paper on which it marks is carried under it by the drum A, which is rotated by a worm and wheel below it connected by a shaft and bevel gear with the road wheel V. The paper is thus drawn from the stock roll C, passed under the pencil, and wound up on the receiving drum B. The result is a profile of the road surface of which the scale is full-size vertically, and $\frac{1}{8}$th inch to one foot longitudinally. A second pencil seen beside P draws a datum line, corresponding to that which the indicating pencil P would produce from a perfectly even road. From this can be measured the depth of the "ruts" or "cups," or other unevennesses indicated on the diagram. The sum of the depths of all these unevennesses constitutes the numerical index of unevenness, and is indicated on the decimal counter W, which is worked as follows:—A cord attached to the free end of the lever T is passed once round the double-grooved pulley X, and connected to the stretched rubber-band at O. When the lever T descends, owing to the fall of the road wheel V, into a rut or cup in the surface, this cord rotates the pulley X by the amount of the drop, the rubber-band O stretching to allow the necessary movement of the cord. When the road wheel and lever rise again, the cord slips back on the pulley, the rubber taking up the slack, while the pulley is held fast by a brake, consisting of a quite similar rubber-tightened cord attached to a rigid part of the

(Mr. John Barr.)

frame instead of the lever T, and passing round a separate groove on X. The pulley X therefore rotates intermittently, in one direction only, to an amount proportionate to the sum of all the unevennesses passed over, which amount is indicated in inches on the decimal counter, and constitutes the index of unevenness.

In order to compare the index of one road with another, it is obviously necessary that the same length of each be taken as a unit. For this purpose a length of 125·3 yards, being one-fourteenth of a mile, is convenient, and this is measured in inches of paper run off the roll C, proportionate to the scale arranged; that is to say, when 125·3 yards of road have been traversed, 47 inches of paper will have run off the roll. Each 47-inch length is measured off by an arrangement placed inside the drum A. On the arm which carries an alarm bell is also a quadrant having three teeth; drum A has a stud fixed inside, and revolving with the drum it carries the quadrant forward one tooth, until three complete revolutions of drum are made when the bell rings, thus indicating that the unit length of road has been traversed. The working parts are protected from passing showers, &c., by a suitable glass cover. The machine is so constructed that it can be folded up into a reasonable compass for easier carriage.

Mr. R. B. Hodgson wrote that to get a really satisfactory means of starting an internal-combustion motor, the same as a steam-engine was started, was one of the most difficult problems for the motor carriage engineer to solve. A compressed-air starter of any form added much to the complication of the machinery, which he thought most engineers would agree was already far too complicated. It must be admitted, however, that there was more fuss made over this question than there need be. Light-oil engines had been made that would start with the greatest ease, only one revolution of the starting handle being required. The great thing was for the driver to know the tricks of his engine, under different conditions (temperature-atmospheric), such as an excess of moisture, &c.; there would then be no difficulty in starting a well-designed and well-made engine with one or two turns at most of an ordinary disengaging handle. In such cases the engine could always be stopped for a few minutes anywhere; of course exception must be taken in cases of congested traffic, when the driver must be ready to start the car at any speed and at any moment. There were to be seen on the River Thames light-oil launches, whose engines were stopped in every lock and started again without the slightest trouble, with no complication in the way of special starters.

On the subject of balancing the internal-combustion engine, it must be admitted that the only engines in which the explosive impulses were balanced were those of the Prelot, Gobron, Hyler-White, and Henriod types. In most of these engines the reciprocating parts were also perfectly balanced. The Henriod type was no doubt the simplest of all, but even this, when at work, had a twisting moment about its crank-shaft centre, which caused some vibration. The points to be considered and the order of their importance, in the balancing of internal-combustion engines for motor carriages, were:—

1st. The balancing of the explosive impulses.

2nd. The balancing of the reciprocating parts.

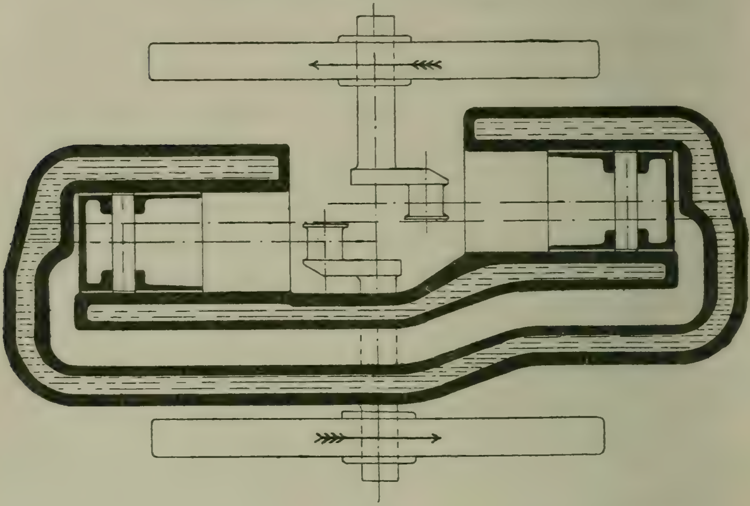
3rd. The balancing of the twisting-moment, or, in other words, arranging to prevent the body of the engine from tending to revolve round its crank-shaft, when the latter was being held by the work.

The writer noticed that there had lately been designed an engine of the Henriod type, which was known as the Bennett-Thomas Motor, in which the balancing faults were overcome. Instead of one crank-shaft with crank-pins set at 180° apart, there were two distinct crank-shafts, arranged on the same centre line with a single crank and a fly-wheel on each, and each cylinder worked its own crank-shaft; but one was made to revolve in the opposite direction to the other, and the work or power was taken equally off each shaft, through a special transmission gear, to the driving wheels of the carriage. The cylinders in this engine were connected by a common tubular combustion chamber, so that it only required one set of valves and one igniter, and therefore both cylinders were effected equally, whether there were a full explosion or a miss-fire.

(Mr. R. B. Hodgson.)

Fig. 62 showed the arrangement of cylinders, crank-shafts, fly-wheels, and the tubular combustion-chamber common to both cylinders. There were, however, other points of interest in this motor, one being that piston-valves had been adopted instead of the mushroom or tappet types; these piston-valves were specially constructed to prevent their leaking during the time compression and explosion took place. The governing of this motor was effected by a common throttle-valve in the feed-pipe by a centrifugal governor on the main shaft, the shaft being extended to carry the governor. It was interesting to note that a motor of this design had been for the past twelve months successfully propelling a small launch on the River Thames, giving 3½ B.H.P. at 650 revolutions per minute, and the motor was started quite easily. The inventors had claimed advantages, such as absence of vibration, noiseless, smooth-running, and simplicity of construction, and judging from what could be seen of it when on trial for propelling launches, the results went to show that the motor gave all the advantages claimed.

Fig. 62. *Bennett-Thomas Motor.*



Mr. DAVID JOY sent a drawing of a farmer's engine, which was practically the present traction-engine. This was built in 1848 by Messrs. E. B. Wilson and Co., of Leeds, and ran about the roads there.

Mr. J. A. MAYS, of the Automobile Club, wrote that in ordinary solid-tyred wheels, such as were used on roads and railways, one saw embodied the absolute relation between radius and circumference, which was involved in the mathematical conception of a circle, and consequently there was found in the wheels themselves no premature or inordinate wear and tear of structure due to internal strains. But in the construction and action of elastic wheels, where the tyres might be made up of springs, of solid rubber, or as pneumatic cells, there were always to be seen ample illustrations of the results of a disregard of this primary law of mechanics. Thus the actual radius at the tread of an elastic wheel would be shorter than any other radius, according to the density of the elastic cushion and the weight of the load. In the case of a driving wheel of 3-feet diameter, for example, a shortening of the radius by half-an-inch only involved a difference of 1 inch in the diameter and 3·14 inches in the circumference. In the course of every revolution, therefore, the wheel travelled a distance of 109·96 inches, the circumference due to the load-radius, as it might be called, of 17·5 inches; but yet while rolling or moving onward only that distance it revolved on its axis through a distance of 113·1 inches, the circumference due to the wheel-constructed radius of 18 inches. There was therefore a "slip" of 3·14 inches, and, on realising this state of things, one was instinctively impelled to reflect as to what the effect of this apparently unavoidable "difference" would be in the course of thousands of revolutions—of the stresses inevitably set up in the materials forming the tyre in the course of a day's work at even twelve miles an hour—and of the probable effect on the life of the tyre of sometimes driving at twice that speed. Theoretical considerations thus amply confirmed and reinforced the evidence of experience, and it became easy to understand how it was that the up-keep cost of pneumatic tyres might amount to four times as much as was expended in propelling the vehicle.

(Mr. J. A. Mays.)

He ventured to offer a suggestion accordingly to the mechanical engineers, to whose careful consideration Professor Hele-Shaw in his opening sentence seemed to canonically commend this great question of road locomotion. Should not the difference between the arc and the chord in the tread of an elastic tyre be automatically adjusted in the tread itself? Was it not desirable, and might it not be possible, to effect a contraction of the circumferential dimensions of the tyre at the tread in the ratio of the radial compression? It was impossible to disregard mechanical laws without incurring penalties, and, what was worse, it was equally impossible to escape from paying them in some form or other. In this case then, who could say how much of the fine of 2*d.* per mile was not due to the cause under consideration?

Turning to another part of the subject, he ventured to question the conclusion which the author seemed to have adopted, as to what might be called the function of the pneumatic tyre, as now made and operated. If the tyre was really to be regarded as a yielding body, which took in or absorbed obstructions on the road surface to such an extent that the total vertical height through which the load was lifted was diminished to a sensible degree, less density of air-cushion than was now resorted to must be postulated, and, per consequence, a continuous shortening of the radius such as no automobilist or cyclist could or would endure, except in very exceptional cases, on account of the increase of internal friction of the substance of the tyre involved in overcoming the correspondingly greatly increased circumferential "difference" already noticed. When the pneumatic tyre first came out, the doctrine of absorption was accepted, so to speak, as being of the foundations of belief, and very graphic illustrations of its action were in vogue. But nowadays the universally accepted principle of faith and practice was "pump hard." Without exception, the tyres in the 1,000-miles run were pumped hard enough to negative the possibility of absorption. Professor Carpenter told them too,* that, as the result of an exhaustive series of mechanical tests, he had found that the efficiency of the bicycle wheel varied between 40 and 70 per cent., that the resistance due to tyre friction decreased on harder blowing, and that the best results were realised at a density of 60 lbs. to the square inch. The true function of the pneumatic tyre, as now made and operated, was not to "absorb" obstacles, but to receive and distribute among its great multitude of air particles—each one of which received its individual share—the more or less minute concussions and blows which the wheel received by reason of its extremely rapid contact with and rebound from slight irregularities of the road surface—the vibration producing action due to concussions which arose with too great frequency to be taken up or deadened by springs interposed between the wheel and the vehicle.

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* Sibley Journal of Engineering, 1897–98, vol. xiii, page 149.

Since it could not be doubted that, whatever their faults might be for the moment, pneumatic tyres must be admitted to be almost absolute necessities of motor locomotion, was it not of vital importance that their deficiencies should be studied and their defects removed? The members of the Institution of Mechanical Engineers, it was to be hoped, would be alive to their opportunities, not to say their duties, in this respect, and he ventured to commend to their careful consideration the possibility of constructing and working (at say a tenth of the present cost of 2*d.* per mile) pneumatic tyres of an ideal type:—An ample nimbus of compressed air held round the circumference of a wheel by an envelope of nominal thickness which would perhaps consequently be subject to but nominal friction upon flexion and which would be incapable of being either pierced or burst asunder in ordinary wear. To this ideal tyre he would also ascribe the property of concurrently modifying its circumference in the ratio of its radius. Then, last but not least, and given these possibilities, which he regarded as conditions essential to "absorption," he would advocate a fairly obvious shortening of the radius, and go in for length of tread rather than for width of wheel. An obvious advantage of a long and flexible tread in traction would be that, regarding the action between the wheel and the road as comparable with that of a rack and pinion, there would, so to speak, be a very large increase in the number of teeth in contact, a very important consideration indeed, both to the wheel

(Mr. J. A. Mays.)

and the road, in heavy work and in hill climbing. In carrying wheels, also, a long and flexible tread would mean that the jolting or concussive effect of rapid contact with obvious obstacles (as compared with those of merely a vibration-producing character), would be largely diminished; for the intensity of the concussion would depend upon the proportion which the area of concussive contact would bear to the whole area of tread of the wheel. Both kinds of advantage were obtainable, too, with a largely diminished intensity of tread; for, the area being increased, the pressure per square inch would be lessened. It might be expected, accordingly, that road authorities, perceiving the lessened abrasive and concussive wear, due to the fairy-like foot-print of such ideal wheels, would be satisfied with less width of wheel than that which a timorous legislation had empowered them to demand.

Mr. WILLIAM MILLS wrote that he quite agreed with Mr. Fowler (page 280) condemning the low maximum tare weight of vehicles, but it was evident from his remarks that his experience was confined to the heavy freight class of motor car only; and the writer was afraid that Mr. Fowler had condemned the use of aluminium from the want of more knowledge and experience in the use of this metal. As the instance he quoted of aluminium being too soft for the purpose, it was evident that pure aluminium sheets had been used, and quite possible the softest grade of this metal. He would point out there was as great a difference between pure aluminium and aluminium alloys as there was between copper and its alloys, such as gun-metal. Far from aluminium being an unsuitable metal for motors, it was an ideal metal for the purpose, and could be used with great advantage almost wherever brass or cast-iron, and even in some cases where wrought-iron was used. Thousands of castings were supplied monthly for such purposes as engine base- and sole-plates, cylinder chambers and air vessels, branch pipes and gear cases, and a great number of other parts too numerous to mention. He had practically never had a single failure with these castings, his experience being that the returns were not so great as in brass. Further, aluminium-alloy castings were supplied for nearly every

English car that ran in the 1,000-miles trial, and he had not heard of a single failure having taken place; this was more than could be said of other materials.

Professor JOHN MILNE wrote that he thought a vibration meter, such as was used on the Japanese railways, should give a good record if placed on a motor car. Fig. 57, Plate 38, showed an example of the sort of diagram which would be obtained. It formed the starting and the finishing portions of a record extending over several days on the Japanese Government Railway between Shinbashi and Kobe. This diagram taken by Mr. J. McDonald showed irregularities due to variations in gauge, want of ballast, springy portions of the road, faults in ties or sleepers, and irregular motions on bridges. The vibration meter or seismograph * had been also used for testing locomotives and carriages. By running the vehicles under similar conditions over the same line, diagrams had been obtained showing the vibrations in a series of successive waves from which both the amplitude and the time taken to describe the wave could be read. In this manner unsuitable balancing in locomotive engines had been detected and corrected. The instrument used for testing vehicles differed from that used for recording the condition of the railway only in the clockwork which drove a drum at a high speed for a short interval of time.

Mr. E. SHRAPNELL SMITH wrote that, the chairman having asked that the discussion be limited to mechanical questions, he had refrained from speaking at the Meeting; but he had much pleasure in sending notes of what he had intended saying.

Mr. Sturmey (page 273) had spoken of its often being better to pass a horse at a moderate speed than to stop an oil car; the point he himself wished to emphasise was that less noise resulted on account of the motor's remaining in gear and not running light.

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* Further information on seismometry as applied to railway trains may be found in a Paper by Professor Milne and Mr. J. McDonald in the Proceedings of the Institution of Civil Engineers, 1890–91, vol. ciii, page 47.

(Mr. E. Shrapnell Smith.)

Mr. Fowler (page 280) had remarked upon the severe shocks in passing over bad pavement, but the remedy was to travel very slowly over such places. Stopping on inclines, for the purpose of allowing the steam pressure to rise, was a question of minutes only, at rare intervals, whilst horses had to take such rests frequently and for longer periods. He regarded such occasional delays as preferable to much larger boilers. Mr. Worby Beaumont (page 285), in criticising the costs per net ton-mile, had complained that no provision had been made for loading, unloading, and other charges, but the charges to which he had referred were common to any system of transport, over and above the costs of conveyance from warehouse to warehouse, or warehouse to ship's side, and had, therefore, nothing whatever to do with the cost "per net ton-mile." A motor wagon possessed no mystical power of discharging its load, neither was any such claimed for it, but consignees had to unload horse-drawn vehicles in the same way. The costs per net ton-mile were put forward, he gathered, to cover the services which were replaced by the motor, not to cover establishment or other additional expenses that remained unaffected by the change, and, as such, they were certainly correct.

He felt that all must unite in regarding the Paper as a valuable contribution to the literature of automobilism. Heavy traffic was of most interest to himself. Early in the Paper, Fig. 1 (page 188), Professor Hele-Shaw went to the root of railway disabilities by showing graphically the significance of terminal charges. For a journey of twenty-two miles, the terminal were about equal to the conveyance charges, whilst they were as much as 50 per cent. at fifty miles. The railway companies stated that these terminal charges could not be reduced. The only hope, then, lay in a reduction of the conveyance charges, when the disproportion between terminals and conveyance—to illustrate which Professor Hele-Shaw said he introduced the figure—was accentuated. In this figure he found a full reply to the theorising engineer who cited the high resistance of our common roads, and the heavy charges for power and labour, as fatal objections to the motor wagon. The fact that the motor eliminated terminals, avoided breaking bulk, and did away with repeated handlings, outweighed the disadvantages of, and the losses due to, the heavy propulsive effort and the high attendance charges.

Passing to Fig. 53 (page 224), where the railway was compared with the motor, he had been at considerable pains, since the reading of the Paper in April, to check Professor Hele-Shaw's figures. The motor figures agreed closely with the experience of Messrs. Fuller (page 237), when allowance had been made for the fact that the average load at Chiswick had been below 3 tons on a unit capable of taking 6 tons.

The railway figures had rather puzzled him, for they were not the sum of the terminal and conveyance charges given in Fig. 1, but this was explained by the fact that cartage at one shilling per ton (each end) had been added, which only served to direct attention to Professor Hele-Shaw's words on page 187. He had ventured to go further into the matter, and had enlarged Fig. 53 up to a journey of 100 miles. Twelve shillings and sixpence had been added for each night's charges upon the motor, and he was surprised to see it still below the railway. When one was dealing with such long distances, it must be remembered that the risk of having no return load was increased.

At the April meeting, Mr. Aspinall remarked (page 247) that ton-mile figures, in the sense which Professor Hele-Shaw had used them, did not exist on English railways. He himself thought that this statement called for close examination. It was true that if one applied to a railway company for a rate, they did not state it in pence per ton-mile or give you the terminal and conveyance charges separately. They had no desire to open one's eyes in the way Fig. 1 did. He conceded that the railway companies did not use ton-mile rates in giving a quotation, but ton-mile rates existed all the same. The maximum conveyance rates were expressly sanctioned by Parliament in "pence per ton-mile," and there was no reason why the terminals should not be expressed in the same way. Let cartage be added, and Professor Hele-Shaw's figures were the result. Mr. Aspinall had also remarked, speaking of the Liverpool Self-Propelled Traffic Association, that "it was a shame for a railway

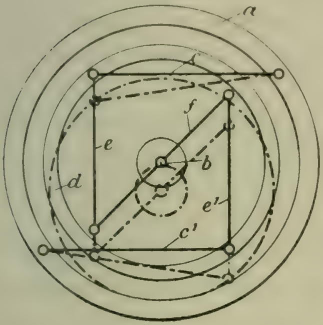
(Mr. E. Shrapnell Smith.)

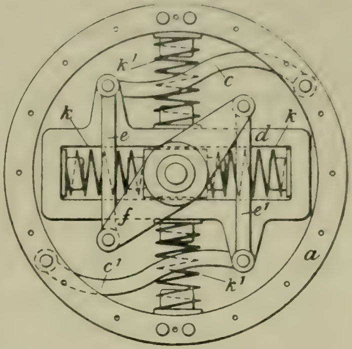
company to take the wind out of their sails," etc. That was quite an erroneous impression, because the Association was a scientific body, not a carrying company. Further, the railway company were by no means the first users or owners in Liverpool. The Association fully appreciated the offer of further figures, for good results upon irregular town work made it more abundantly clear that success would attend the working of traffic under more favourable conditions. The Association could also understand the disappointment felt in some quarters at their not approving a premature start by Liverpool merchants and shipowners. Since the last meeting of the Institution the conditions for the 1901 trials had been issued, and these formed the best answer he could return to those who thought the Association had not been doing anything lately. In Liverpool time and money had been spent, they had had papers and discussions, and had organised three series of trials; they believed that the motor wagon was, for certain purposes, superior to either the railway or the traction engine; they had the courage of their convictions and, to use a phrase that had been popular of late, they meant to see the thing through.

Mr. M. HOLROYD SMITH wrote that, in continuation of his remarks at the Meeting when commenting upon Professor Hele-Shaw's Paper (page 293), he now sent three diagramatic drawings illustrating the principle of the method of constructing spring wheels.

Fig. 63 represented the hub of a wheel from which wire spokes could go to the ordinary rim or tyre; *c* and c^1 were a pair of rods or levers hinged at one end to *a*, and at the other end to a ring *d*, which formed a connecting link between the two levers. It would be seen that *d* could move up or down in the vertical direction, but it could not move horizontally. At or near the junctions of *c* and c^1 with the ring *d* two other rods or levers *e* and e^1 were hinged, the other ends of which were hinged to the link *f* forming part of or being keyed to the axle *b*. It would be seen that *b* could move horizontally in reference to *d*, but could not move vertically in reference to *d*; but inasmuch as *d* itself could move vertically, *b* could move anywhere from the centre outward in its relation to *a*, therefore the axle had a perfect radial movement relative to the rim or tyre of the wheel. The link *d* was not necessarily circular but could be made of any convenient shape; for example, an oblong as shown in

Fig. 63. *Spring Wheels.* Fig. 64.





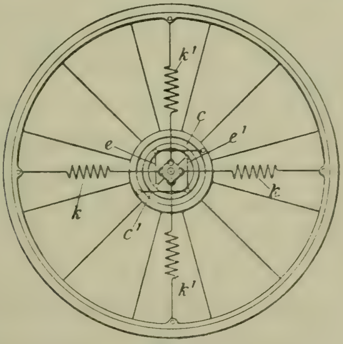


Fig. 65.

Fig. 64, permitting the restraining spring *k k* being interposed between it and the axle block to restrain horizontal movement, and on k^1 k^1 between itself and the enlarged hub *a* to restrain vertical movement.

The terms horizontal and vertical were used for convenience in describing the diagrams; as the wheels rolled they were, of course, ever changing, and when they were both diagonally situated, the downward movement of the axle would be a compound of the two

(Mr. M. Holroyd Smith.)

movements; hence the term "a compound parallel movement." The springs did not need to be located within the enlarged hub, but could be applied as shown at *k k*, k^1 k^1, in Fig. 65.

The compound parallel rods and links took all the torsional strain and yet permitted a radial movement, restrained only by the spring. It would be noticed the springs acted only in one sense, when enclosed in the hub always in compression, and when as shown in Fig. 63 always in tension. Those who had had to deal with springs would see the importance of this.

Whilst listening to Mr. Henry McLaren's remarks (page 297), he felt that Mr. McLaren must have misunderstood his sketch and description, both of which he fully admitted were fragmentary. The writer therefore has had some correspondence with Mr. McLaren; and now that the latter has had a complete drawing and description submitted to him, he expressed himself satisfied that Mr. Holroyd Smith's idea was distinctly novel, and that his arrangement in no way anticipated it. The writer certainly was not aware of any spring wheel having been made in accordance with the arrangement suggested. He would also like to add that he was an advocate of electric ignition in motor engines, and had experimented therewith four years ago, and had then pointed out the advantage of the timing arrangement Professor Hele-Shaw had been good enough to describe. On some future occasion the writer might be able to give a solution of the difficulty he had raised.

Mr. SYDNEY F. WALKER wrote that he would like to endorse the remarks of the author of the Paper on the matter of electrical accumulators. He did not suppose any one really doubted that the autocars of the future would be driven by electric motors, but the problem of the accumulator to furnish the current for driving the motor was a very difficult one. The conditions necessary for automotor work were the worst possible for the accumulator. Where space was unlimited, where weight was not of importance, and where the cells were always open for inspection, the electrical accumulator was a useful and fairly economical apparatus—as in the case of the lighting of a country house; but where space and weight were limited, and without convenience for inspection, the accumulator became most wasteful, in every sense of the term. As the author had remarked, the wash of the acid and the general jarring of the whole thing broke little pieces off the active material, which fell between the plates, short-circuiting them, and taking out of them uselessly, in a few minutes, energy that would carry the car some miles. In country house work this did not matter, if it did occur, as the chips fell harmlessly to the bottom of the cell; but in the accumulator for motor cars, there was no room to spare for this, and so the chips stuck between the plates. In addition, the plates themselves were made light to reduce the weight; when what was required was increased weight, because that meant increased strength.

It was well known that the passage of the electric current through any metal, particularly if the metal was in the position that the current left the apparatus at that point, tended to make the metal brittle, with the result in the case of the portable accumulator that the plates themselves tended to break up, quite independently of the electrical action. The cells themselves individually also had an awkward knack of occasionally reversing in the operation of discharge. This meant that, in addition to the loss of the energy that should be available for useful work, a portion of the plates of the cells which behaved in this way were "commandeered" in the process of putting the matter right.

He would also like to endorse what the author stated as to the evils of connecting the cells in parallel. Even while the cells were nominally furnishing their normal E.M.F., considerable waste took place if the practice was indulged in. In theory the cells were supposed to be furnishing the same E.M.F., so that when two groups of cells were connected in parallel, no current was supposed to flow, except when the external circuit was complete; and then each group contributed equally to the total current going out. In practice nothing of the kind took place. No two cells, nor any two groups of cells, ever gave the same E.M.F., or presented the same resistance; or if they did by chance, the equality was not maintained for any time. Consequently, one group of cells being more powerful than

(Mr. Sydney F. Walker.)

the other, having a higher E.M.F., the group with the lower E.M.F. could not discharge; and in addition, the weaker group formed a path for the discharge of the stronger, not only when discharging to the external circuit, but while the battery as a whole was supposed to be at rest, with the result that the two groups were overworked in turn. The group most powerful at first worked down under the strain of the additional useless work it was performing, and in time became weaker than the other group. The second group then took up the work both externally and internally, and worked down in its turn, and so on. In addition to the extra work that the cells thus performed, there was the increased possibility of reversal of individual cells, with all the attendant troubles. It might be necessary at certain times to arrange the cells temporarily in parallel, as at starting, hill climbing, &c., but they should only be allowed to remain so for the shortest possible time. The solution of the problem, he ventured to think, would need a radical departure; and he ventured to repeat a suggestion that he had made in a discussion on the subject at another Institution, namely, that the supporting plates should be made of aluminium, platinum, or some other light strong metal, the active material being superposed on a framework of one of these metals. The writer was of course aware of the objections respecting the galvanic action of two dissimilar materials, &c.; but as there was in the accumulator, as now arranged, the most powerful galvanic couple known at the present day on each of the positive plates, in the lead lead-oxide sulphuric acid, and a less powerful but somewhat similar cell on each negative, the matter was certainly worth looking into.

Professor HELE-SHAW wrote that a study of the spoken and written discussion would amply bear out his opening remarks as to the wide range of the subject. It had included legislation, cost, roads, wheels, tyres, steering, balancing, vibration, noise, smells, smoke, and danger, gearing, carburettors, igniters, electricity, self-starting, methods of cooling, boilers, the use of aluminium, and numerous other points of interest. Several of the questions raised had been answered by subsequent speakers or in writing. Thus the question of cost in connection with heavy motor vehicles and the commercial aspect generally, which really was at the root of the matter, had been dealt with by Mr. Shrapnell Smith (page 312), who had answered the remarks both of Mr. Aspinall (page 247) and Mr. Worby Beaumont (page 285) on that subject as far as it was possible to do at present. Again, upon other points there was absolute agreement in all that had been said and written. The most important of these was that of legislation in respect to the 3-ton tare limit. He ventured once more to express the hope that some practical steps would be taken in the direction of raising that limit, and that the Council of the Institution would assist that of the Automobile Club in bringing pressure to bear in the proper quarter. Since the discussion had concluded, the draft report of a committee, of which he was a member, had been issued on the working of the 3-ton tare limit, and had been reprinted in the "Automotor Journal" (August 1900, page 577), in which the case was stated under four heads:—(*a*) Motor compared with horse haulage; (*b*) the safety of the public; (*c*) commercial requirements; (*d*) foreign competition. It was there urged that a new Bill should be sought "To allow light locomotives which shall otherwise conform with the requirements of the Locomotives on Highways Act of 1896 to be constructed and used under the provisions of that Act, provided the weight per inch width of tyre on any wheel shall not under any conditions of running exceed 12 cwt." Such a law would surely secure efficient protection of the roads far better than the present Act.

On other matters speakers and writers had rather contributed information than advanced any criticisms, but there were two or three points which called for a reply. Mr. Holroyd Smith (page 290) had said that though the usual method of steering (commonly known as Ackermann's) "was very good when going forward, it was altogether wrong when going backward." This was the first time he (Professor Hele-Shaw) had ever heard this view advanced, and all his own experience in driving was entirely against it, for as far as he knew motor cars steered just as well backward as forward. Those who had watched a skilful driver like Mr. Rolls would remember that he could steer backward at a speed at which very few ordinary drivers

(Professor Hele-Shaw.)

would care to move forward. Apart from this, however, what he had meant in describing the steering gear of Mr. Davis as "perfect" was merely in a geometrical sense, and Mr. Holroyd Smith would find a full description of it given in a former issue of the "Automotor Journal," in which the geometrical proof was duly set forth.

Mr. J. A. Mays (page 307) had discussed in an interesting way the action of the pneumatic tyre, but his remarks concerning the rolling of an ideal wheel upon the ground applied really to a perfectly smooth and hard track. The road which the motor vehicle had to traverse was unfortunately neither smooth nor hard. Hence his reasoning about the relation between circumference and radius which, though it accounted for some loss of power, overlooked the chief cause of loss, namely, the energy absorbed in deviating from its path a heavy body like a motor-car, weighing possibly more than a ton and travelling at a high speed. With hard tyres the car, or a portion of it, must be lifted at every small stone which it did not crush. What the pneumatic tyre did was to absorb such small obstacles and prevent the upward deviation. If Mr. Mays would calculate the loss of energy from such a cause at a speed of even twelve miles an hour, he would at once see that the explanation which he himself went on afterwards to give, namely, that the true function of the pneumatic tyre was to receive and distribute an innumerable number of minute concussions and blows, was only saying in another way that loss of power and injury to the vehicle were avoided by what seemed expressed very well by the term "absorbing" the obstacles. The hard pumping which had apparently misled Mr. Mays was only to obviate undue yielding which, of course, caused unnecessary loss of power and wear of the tyre without preventing to any appreciable extent the small, hard obstacles being absorbed. So far from the hard pumping being a modern idea its importance had been perfectly familiar to all who had experimented with and used pneumatic tyres from the early days of their invention. Several speakers had dealt with balancing, and he was sorry that it was now impossible to go into this question and add to what had been said. There must be some end to a discussion of even the length of the one upon his Paper, even if some matters were unavoidably left out. He was reminded of a remark made by a President at a British Association Meeting—that so many papers were now published that a man not only could not read what had been written by others on his own subject, but very soon would not be able to read all he had written himself.

MEMOIRS.

Frederic William Barker was born in London on 18th February 1862, and was educated at private academies. Having developed a talent for drawing and designing, he became chief draughtsman at the age of twenty to Messrs. John King, heating and ventilating engineers of Liverpool, and in 1886 was appointed their manager. During this period he superintended the installation of the heating and ventilation arrangements at the Liverpool University College with its Tate Library and the Jubilee Tower at Liverpool, and at other important buildings. In 1891 he invented a tubular automatic exhaust ventilator and an improved radiator, both of which were adopted by the firm and proved highly successful. In 1894 he went to London, where he started business on his own account as ventilating and consulting engineer, and invented and introduced new designs and improvements in various ventilating appliances. After a very short illness he died at his residence at Chiswick, London, on 9th February 1900, in his thirty-eighth year. He became an Associate Member of this Institution in 1893.

William Duff Bruce, son of Mr. George Williamson Bruce, was born on 10th April 1839, at Brooklawn, near Mowhill, County Leitrim, Ireland. At the age of nine he was sent to St. Andrews, and remained there until he was sixteen years of age, when he returned to Ireland, and studied engineering with Messrs. Thomas Grendon and Co., of Drogheda, a firm largely engaged at that time in the construction of locomotive engines, marine engines, and general millwright work. Having spent four years in the shops, he subsequently followed up his studies at St. Andrews with a course of engineering with a view to competing for the Indian Public Works Service.

He took second place at the public competition, and was thereupon appointed to the Public Works Department in India. On arrival in that country in December 1860, he was sent to Roorkee College in order to study engineering further, and to acquire a knowledge of the language. Six months later he was appointed assistant engineer in the Cawnpore Division of Public Works, and was placed in charge of the Futtegarh Sub-Division where he built the memorial church, erected in memory of the residents who had been killed during the Mutiny. From there he was transferred to Oude, on receiving the appointment of assistant to the chief engineer and secretary to the Chief Commissioner in the Public Works Department in Lucknow. He retained that appointment for two years, and was then promoted to the position of executive engineer and appointed to the Lucknow Division of Public Works, where roads and barracks in the new military cantonment were carried out under his direction. He also designed and built the bridge across the Goomtee, three spans of 80 feet each, in brickwork.

In 1867 he was again transferred from the Lucknow Division to Calcutta, where he was appointed executive officer in charge of the second Calcutta Division, in which was included all the new public buildings then being constructed, namely, the telegraph office, the new High Court, and the Indian Museum. After spending three years in this position, he was promoted to the Hooghly River Division, which included the charge of the new wharves and jetties, and the carrying out of improvements for facilitating the landing and shipping of goods at Calcutta. In 1870 the whole of these works were placed under the Port Trustees, a body formed on the same lines as the Mersey Docks and Harbour Board, and styled the Commissioners for making Improvements in the Port of Calcutta. Of this body he was appointed vice-chairman and chief engineer. In that capacity he designed and carried out all the works for the improvement of the Port. In 1873 the works on the Hooghly between Calcutta and the sea were transferred by Government to the charge of the Calcutta Port Commissioners, and in his official capacity as engineer and chief executive officer, he had then charge of the lighthouses, lightships, and the survey of the river, and of all works which were carried out from that time till his retirement in 1889. In 1882 the question of providing docks at Calcutta was brought forward, and after much investigation sanction was given to a scheme prepared by him. The docks were commenced in 1884. A full description of these works was given by Mr. Bruce in a Paper read at the Institution of Civil Engineers.* The cost of constructing the docks and works connected therewith was about £2,250,000. He continued in charge of the Works in India until 1887, when he returned to London in the capacity of consulting engineer to the Port Commissioners. In 1889 he retired from the service, but retained his appointment of consulting engineer to the Port Commissioners. The records of the Commissioners' Proceedings show how highly his services were appreciated, and with what success he had so long filled the responsible position of Chief Executive Officer of the Port.

In 1887 he commenced business at Westminster as a consulting engineer. He was appointed consulting engineer to the Delhi Umballa Kalka Railway, and in 1890 to the Assam-Bengal Railway Company, concessions for both of which he obtained from the Secretary of State. He was also connected with the establishment of ironworks in India, which, after many years of difficulties, are now being profitably carried on, his untiring zeal very largely contributing to the success which has been attained in this direction. For some years he had been a director of the Rio Tinto Company, and at the time of his death filled the position of deputy chairman. His firm also acted as consulting engineers to the company. Many important changes were carried out at his suggestion, and his technical skill has been of great service to the company. His death took place in London on 24th April 1900, at the age of sixty-one. He became a Member of this Institution in 1867, and was also a Member of the Institution of Civil Engineers.

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* Proceedings Inst. C.E., vol. cxxi, page 88.

THOMAS BUCKNEY was born at Bankside, London, on 1st December 1838. He acquired the whole of his practical knowledge during his connection with Messrs. E. Dent and Co., clock and watch makers of London, with whose business he had been connected nearly all his life. He was appointed superintendent of the manufacturing department in 1864, which post he held until 1872 when he became a partner. A few months later, on the death of his father, he became senior acting partner, and senior partner in 1881. He was able to make any piece of work that fell within the limits of his business, extending from watches to the largest turret-clocks. He designed the standard sidereal clock of the Royal Observatory, Greenwich, and made with his own hands the more delicate parts of the escapement. He also made the chronographs for the observatories at Brussels and Tokyo; and arranged the clocks used for observing the transit of Venus in 1872. His firm were the makers of "Big Ben" at the Houses of Parliament, Westminster. He was the designer of electric contacts for marine chronometers; and one of his latest and best works was the great clock recently erected at Gloucester Cathedral. In 1880 he read a Paper to the Royal Astronomical Society, of which he was a Fellow, on a proposed new uniform-pressure clock. He was a Member of the Worshipful Company of Clockmakers, and of the British Association Committee appointed for the adoption of a standard system of screw-threads for electrical and other apparatus. His death took place at his residence in London after a short illness on 1st February 1900, at the age of sixty-one. He became a Member of this Institution in 1886.

FREDERICK HENRY BUTTER was born in 1847. In 1862 he commenced an apprenticeship with Mr. J. C. Evans at the Morden Iron Works, East Greenwich, London. On its completion in 1867 he was employed by Messrs. J. and G. Rennie, with whom he worked until 1869, when he went to Messrs. Ravenhill's works at Blackwall. From 1870 to 1872 he worked at Chatham Dockyard, and in the latter year went to Woolwich Arsenal. There he had charge of the boilers, engines, and machinery, and superintended the general operations of the carriage department. His death took place at his residence at Abbey Wood, Kent, in December 1899, at the age of fifty-two. He became a Member of this Institution in 1888.

Herbert Churchill Capel was born at Capelton, Canada, on 5th July 1862; and was educated at the Home and Colonial Schools, King's Cross, London, and also by private tutors. In 1879 he was employed at the works of the Sun Gas Machine Co., Southwark Street, London, and later at Messrs. Weston Brothers, brass finishers, Hatton Garden, London. He served his apprenticeship with Messrs. Head, Wrightson, and Co., Stockton-on-Tees, and with Messrs. Ladd and Co., American baling-press engineers, London; and in 1882 went to the United States to superintend the design and construction of larger presses. In 1883 he returned to London, and became engineering assistant and draughtsman to the same firm. While with them he designed the perpetual hay and straw-baling presses and the automatic peat-baling machinery afterwards made by this firm. He became works manager in 1886, which position he held until the patents were sold in 1890, when the works were closed. In 1890 he started in business in London, trading as Messrs. Capel and Co., engineers and gas-engine manufacturers, and in 1895 new works were erected in Dalston, and equipped for the production of gas and oil engines on the American system of manufacture. These works have been added to recently. In 1896 he commenced a series of experiments jointly with Mr. Thomas Clarkson in connection with steam-propelled vehicles, and in 1898 he designed and built a petrol motor vehicle. In 1899 he visited the United States with Mr. Clarkson, where they negotiated the sale of the American rights of their various patents relating to oil burners, generators, and coolers for steam motor cars, etc. After his return home he became ill, first with influenza and later with typhoid fever, to which he succumbed on 31st December 1899, at the age of thirty-seven. He became a Member of this Institution in 1899.

John William Carrack was born in Leeds on 30th July 1862, being the son of Mr. Charles Carrack, a Member of this Institution.

At seven years of age he removed to Nottingham with his parents, and received his education at the People's College in that city. From 1875 to 1883 he served his apprenticeship with Messrs. David New and Co., engineers and tool makers, Nottingham, attending the science classes at the Mechanics' Institute in the evenings. He afterwards worked a short time with Messrs. R. Waygood and Co., London, keeping up his studies at the Birkbeck Institution. Returning to Nottingham in 1885 he went to work at the Nottingham Hosiery Machine Building Co., where in 1896 he rose to the position of works manager. He invented several improvements in the application of modern tools for the manufacture of hosiery and other fabric machines; and still continued his studies at the Nottingham University, taking many prizes and medals in the examinations. His death took place at Nottingham from pneumonia after a short illness on 20th March 1900, in the thirty-eighth year of his age. He became an Associate Member of this Institution in 1899.

Thomas Daniels was born at Stony Stratford, Buckinghamshire, on 8th August 1841. He served his apprenticeship from 1857 to 1862 in the locomotive works of the London and North Western Railway at Wolverton, commencing under the superintendence of Mr. J. E. McConnell and finishing under Mr. John Ramsbottom, Past-President. He next gained further experience in Glasgow, and at the Great Northern Railway Works, Doncaster, and also at Earle's marine-engine works, Hull. From there he went in 1865 to the Worcester Engine Works, where he was made foreman of the machine shops. In 1871 he was appointed foreman of the erecting shops at Messrs. Sharp, Stewart, and Co.'s works, Manchester; and in 1883 he became works manager to Messrs. Nasmyth, Wilson and Co., Patricroft, a post which he retained to the last. For the past four years he was also a director of the same firm. About three months prior to his death he had an attack of influenza, and before he had entirely recovered returned to his work. In consequence a relapse ensued, and, complications arising, his death took place on 6th March 1900, at the age of fifty-eight. He became a Member of this Institution in 1891; and was President of the Manchester Association of Engineers in 1893 and 1894.

BERNARD DAWSON, the only son of the late George Dawson, M.A., was born at Edgbaston, Birmingham, on 19th January 1851. He received part of his education at Bromsgrove Grammar School, on completion of which he was entered as pupil with Messrs. Hopkins Gilkes and Co., Tees Engine Works, Middlesbrough, with whom, after having served his time, he remained for a short period, being chiefly engaged in superintending some of their out-door contracts, principally in constructional iron work. Following this, he became sub-manager to the Clay Lane Iron Works near Middlesbrough, leaving there to take up the managership of the Lincolnshire Iron and Smelting Co., at Frodingham. Resigning that appointment in 1877, he was for a time with Messrs. Westray Copeland and Co., at Barrow-in-Furness. In 1880 he commenced practice as consulting engineer at Malvern; afterwards, in 1883, his business increasing he found it necessary also to have an office in London. Having become interested in the patents of the Wilson gas-producer in the early days of his practice, he devoted himself more especially to the question of gaseous fuel, and in this direction he was instrumental in getting this process introduced into almost every branch of industry in the United Kingdom. He afterwards brought out his well-known continuous working gas-producer, which has been adopted by most of the leading firms in the iron and steel trades at home and abroad, as well as by railway companies and general industrial works; and in January 1891 he contributed to this Institution a Paper on "Some different kinds of Gas Furnaces" (Proceedings 1891, page 47). He made a speciality of Siemens' acid and basic open-hearth steel plants, together with gas-fired furnace work of all kinds, in connection with which he designed and carried out many important contracts both for this country and abroad, including the government arsenals at Cossipore in India, the Chinese Arsenal, Earl Dudley's Round Oak Works, and many others. Latterly he also brought out a gas crucible steel-melting furnace, which is now successfully working in Sheffield, and bids fair to bring about important changes in this industry. He took a great interest in the welfare of railway servants, and had from his youth upwards done good work for the Railway Benevolent Institution and the Railway Orphanage at Derby, having for the latter Institution for many years occupied a seat on the Committees. His death took place at his residence, The Laurels, Malvern Link, from heart affection, after an illness of fourteen months' duration, on the 3rd March 1900, at the age of forty-nine. He became a Member of this Institution in 1879. He was also a Member of the Iron and Steel Institute, and of several other Societies; and was the author of works and papers relating to his own special class of work.

James Deas was born on 30th October 1827 in Edinburgh, where his father was engineer of the Edinburgh and Dalkeith Railway, and later of the Edinburgh and Glasgow Railway. It was on these lines that he commenced his training, serving an apprenticeship with his father. He was next for three years in the office of Mr. John Miller, civil engineer, Edinburgh, and thereafter took part in the construction of various railways in the south and west of Scotland, ultimately becoming chief engineer of the Edinburgh and Glasgow Railway; and, upon the absorption of that concern by the North British Railway, he acted in the same capacity on the western section of the company's system for a short time. In 1869 he became engineer-in-chief of the Clyde Trust. The magnitude of the work carried out under his direction during the past thirty years can be seen from the following figures. The quayage has been increased from 3·18 to 18½ miles, and the water area from 76 to 209 acres. There were then three shipbuilding yards, and Napier's dock, occupying water frontage where quays now exist. The harbour then terminated barely a mile below Glasgow Bridge; and now it extends westward a mile and a half further, with extensive docks on both sides and the Yorkhill Wharf, where thousands of cattle are landed. The river, as well as the harbour, has been deepened by 5 feet for the 18 miles under the jurisdiction of the Trustees. By removing the Elderslie rock from the channel of the river there is now 20 feet at low and 30½ feet at high water above the rock, instead of only 8 feet in 1869. In addition to increasing the dock accommodation, he built passenger wharves at Govan and cattle wharves at Shieldhall. When he became engineer there were only two cross-river ferries, now there are about fifteen; and in addition he had a large part in organising the service of penny steamers up and down the harbour. An extensive system of railway sidings has been laid throughout the harbour. When he became engineer there were no cranes for shippers' use—there were only five possessed by the Clyde Trust—now they are dotted all over the harbour, and range up to 130 tons, of which lifting power there are two. During the same period the revenue of the Trust has increased from £150,000 to £428,000, and the vessels frequenting the harbour exceed four million tons annually. At the Edinburgh Meeting of the Institution he contributed a Paper on the Improvement of the Clyde Navigation above Port Glasgow;* and at the Glasgow Meeting he read a Paper on the Clyde Navigation,† which gives an interesting description of the docks, quays, and appliances used on their construction. He was joint inventor with Mr. Nairn, also of the Clyde Trust, of a digger which was largely used in connection with excavating the interior of the triple cylinder of concrete introduced by him for quay walls. Another invention of his was a railway switch-box. His death occurred suddenly from an affection of the heart while lunching in a Glasgow restaurant on 29th December 1899, at the age of seventy-two. He became a Member of this Institution in 1887.

GEORGE HENRY GIBSON was born at Harwich on 23rd July 1852. He served his time from 1868 to 1874 with Messrs. Hawks, Crawshay and Sons, of Gateshead; and on its completion was engaged as draughtsman for two years at the Barrow Shipbuilding Works. In 1876 he was appointed resident engineer for harbours and jetties in South Australia, and remained in that position for eight years. On his return to England in 1884 he became outside manager with Messrs. Francis Morton and Co., Garston, Liverpool, in whose employ he stayed until 1894, when he commenced business for himself as engineer and contractor at Garston. About a fortnight prior to his decease he had stepped off an omnibus while in motion, and fell heavily to the ground. He was able however to walk home, though much bruised and suffering from internal pains, and appeared afterwards to improve in health, but his death took place suddenly at Garston, from aneurism on 9th December 1899, at the age of forty-seven. He became a Member of this Institution in 1898.

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* Proceedings 1887, page 402.

† Proceedings 1895, page 404.

JOHN CLARKE JOHNSON was born at Wheelock, Cheshire, on 19th December 1840. At the age of sixteen he went to Wednesbury, and served an apprenticeship of five years with Messrs. James Russell and Sons. After passing through every department, he rose to be works manager, a post which he held from 1870 to the time of his death. He was well known among the manufacturers and trade representatives, not only throughout the country but on the continent as well; and he may be said to have grown up with Messrs. Russell and Sons' Crown Tube Works. His death took place at his residence at Wednesbury, from suppressed gout, after an illness of ten days, on 24th February 1900, at the age of fifty-nine. He became a Member of this Institution in 1885.

The Hon. JAMES MARTIN was born in 1821, at the village of Foundry, in the parish of Stithians, Cornwall. He received little schooling, and at an early age had to try to earn his own livelihood. After a little experience he went to Truro, and worked for a millwright. He was next employed at the Tresavean mine, Gwennap, and while there was connected with the adoption of the first man-engine used in England. This contrivance was invented by the engineer of the mine, and young Martin was deputed to make the model of it; that model is now in the Polytechnic Hall at Falmouth. Subsequently he gained experience in a woollen factory at Ponsanooth, near Penryn, where he had to do all kinds of work. His determination to overcome obstacles was the secret of much of his success in after life. Becoming a victim to asthma, he determined to settle in a warmer climate, and South Australia was his choice. He arrived in that colony in 1847, and settled in

Gawler as a wheelwright. The site of his workshop is now a very small portion of the area occupied by Messrs. Martin and Co.'s works, which, grown out of that small beginning, now cover eighteen acres. He began operations with one man, and at the time of his death was employing about 700. As agriculture extended, he took up the manufacture of reaping machines and other agricultural implements, and during the last ten years built for the South Australian Government about 150 locomotives, in addition to which the firm have built locomotives for Western Australia and Tasmania. Among the numerous mines to which they have supplied machinery, batteries, &c., are the well-known Broken Hill Proprietary, Lake View Consols, Golden Horseshoe, &c. Notwithstanding the great demand which his extending business made upon his attention, he identified himself with every important local movement. He was Mayor of Gawler for eight years; and was first elected to a seat in the South Australian Parliament in 1865, which he resigned three years later, when he took a trip to this country. In 1885 he was elected a member of the Legislative Council, retaining the seat until the time of his decease. Latterly he had suffered from chest trouble, which gradually became worse, and his death took place at his residence in Gawler, on 27th December 1899, in his seventy-ninth year. He became a Member of this Institution in 1889.

JOHN McQUEEN was born in Scotland on 4th August 1845. He served his apprenticeship with Messrs. Parr, Curtis, and Madeley, makers of cotton machinery, and in 1861 transferred his services to Messrs. John Hetherington and Sons, Vulcan Works, Manchester. Passing through the various stages of fitter, turner, and draughtsman, he became manager, which position he held for fourteen years. In 1886 he became a partner in the firm. Finding that the growth of the business had increased so rapidly, it was decided to transform it into a company in 1890, when he became vice-chairman and managing director. As chief commercial representative of the firm he visited the principal countries of the world, where the English system of cotton-spinning is established. For some time his health had been declining, and he went to North Wales, but no benefit was obtained, his death taking place at Manchester from diabetes, on 15th April 1900, in his fifty-fifth year. He became a Member of this Institution in 1894.

The Hon. NOWROSJEE NESSERWANJEE WADIA, C.I.E., was born in Bombay in 1849. He was sent to England to be educated, and returned to his native country at the age of seventeen, when he became assistant engineer under his father at the Royal Mills, Bombay. He was soon appointed manager of the Royal Albert Mill, and while there turned his attention to the construction of machinery for paper-making. In order to study the subject thoroughly he came back again to England. On his return to India in 1871 he was appointed manager of the Maneckjee Petit Mills, and subsequently superviser and consulting engineer to several mills of the same group. Later on he designed and built several other mills. His English education had led him to see the necessity of technical instruction if India wished to compete successfully with Europe, and by his energies the Victoria Jubilee Technical Institute in Bombay was established. He was the pioneer of the hosiery and sewing-thread manufacture in India, and opened a dyeing manufactory at Mahim; he was the chief promoter of the City and Guilds examinations in Bombay, the chairman of the Joint Schools Committee, and was identified with a large number of the most successful establishments in the Bombay Presidency. During Lord Reay's term of office he became a Member of the Legislative Council, and took a leading part in the passing of the Boiler and Factory Acts and in the legislation connected with the yarn duties. He also took a large part in municipal matters and served on many committees. In 1888 he was created a Companion of the Order of the Indian Empire. His death took place while in this country at Bournemouth on 19th December 1899, at the age of fifty. He became a Member of this Institution in 1879.

Sir RENNY WATSON was born at Hawick on 15th July 1838, his father being Mr. Thomas Watson, manufacturer, and one of the bailies of Hawick in 1839. He served his apprenticeship of five years with Messrs. James Melrose and Sons, of Hawick, at the completion of which he spent a year with Messrs. Gourlay Brothers, of Dundee. He next went to Oldham, and entered the service of Messrs. Platt, Brothers and Co. In 1862 the great Exhibition was held in London, and this firm had several specimens of their machinery on view under his charge. He remained with them nine years until 1868, having latterly been their representative in Glasgow. In that year he became a partner in the firm of Mirrlees and Tait, the style being then changed to Mirrlees, Tait, and Watson. He was also a partner in the firm of Watson, Laidlaw, and Co. Apart from his business pursuits, he took a keen interest in literary and scientific movements, being president of the local branch of the Royal Geographical Society. He was a director of the Glasgow Workmen's Dwellings Co., of the National Bank of Scotland, and was chairman of the Victoria Infirmary Governors. He was created a Knight in 1892. On the occasion of the Glasgow Meeting of this Institution in 1895, he acted as chairman of the Reception Committee. For some time he had been in failing health, and had to relinquish much of his public work. Recently he gave up his position of chairman of the Glasgow and South Western Railway. His death took place in Edinburgh on 7th April 1900, in his sixty-second year. He became a member of this Institution in 1879.

Andrew Wyllie was born at Montrose on 5th January 1823, and was educated at the Montrose Academy. In 1839 he was apprenticed to Messrs. R. and W. Hawthorn, of Newcastle-on-Tyne, where he served five years in the workshops. On the completion of his apprenticeship he worked for a short period in the shops, and then went into the drawing office where he remained about four years; after which he returned to his native town, and became a partner in the Montrose Foundry. In 1853 he removed to Liverpool, and entered the works of Messrs. George Forrester and Co., Vauxhall Foundry, as manager. In the following year he joined that firm as a partner, and remained there until 1887, when he retired from business. He contributed to this Institution a Paper on a Portable

Steam-Riveter in 1865 (Proceedings, page 129). This riveter was referred to by Mr. Macfarlane Gray in his remarks at the February Meeting, 1900 (Proceedings, page 151). His death took place at his residence in Southport after an illness of a few days on 26th January 1900, at the age of seventy-seven. He became a Member of this Institution in 1865.

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ROAD LOCOMOTION.

Vibrations due to Road Surfaces, recorded by Viagraph.

Macadam (Fairly Good).

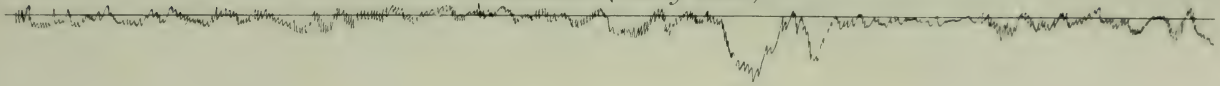


Fig. 5.

Deep depression shows crossing.

Macadam (Bad).

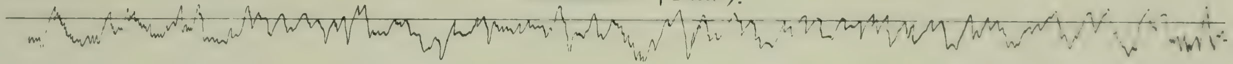


Fig. 6.

Sets (Bad).

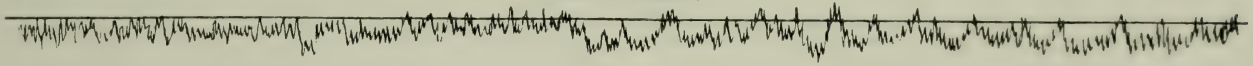


Fig. 7.

Asphalte.

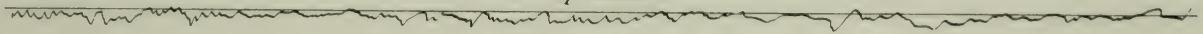


Fig. 8.

Wood (Old).

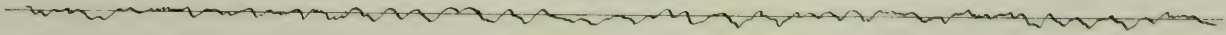


Fig. 9.

Scale 1/3rd Full size.

Pneumatic Tyres.

Fig. 10. *Dunlop (English).*

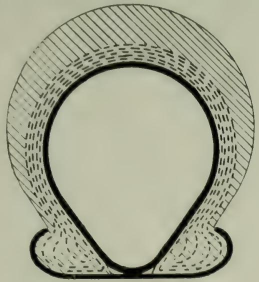


Fig. 11. *Michelin (French).*

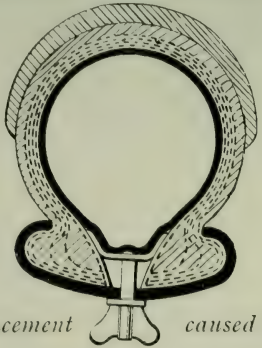


Fig. 12. *Callus (French).*

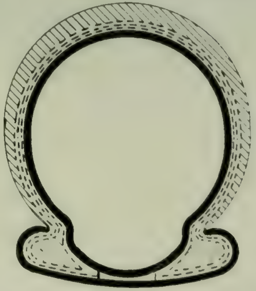
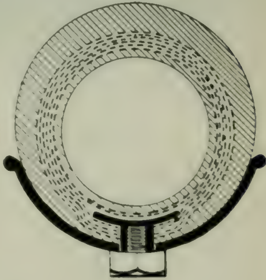


Fig. 13. *Goodyear (American).*



Relative Displacement caused by Iron and Pneumatic Tyres at high speeds.

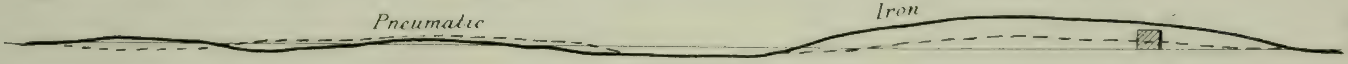


Fig. 14.

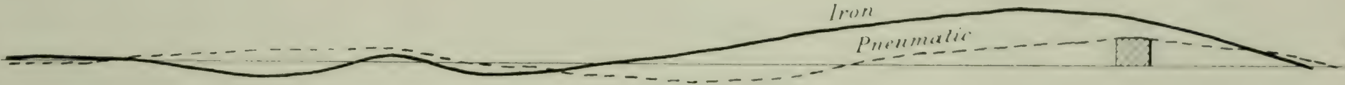


Fig. 15.

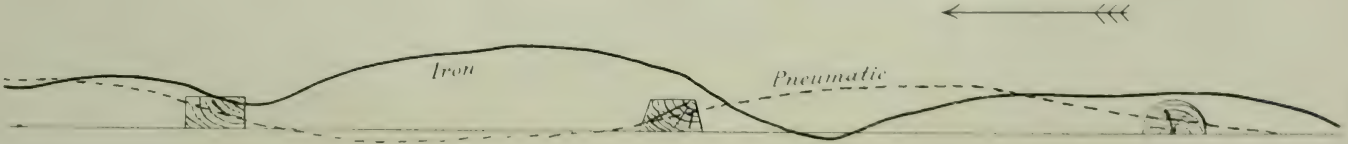


Fig. 16.

ROAD LOCOMOTION.

Types of Driving Wheels for Heavy Motor Vehicles.

Fig. 17. *Leyland.*

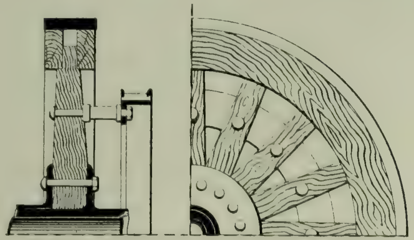


Fig. 18. *Thornycroft.*

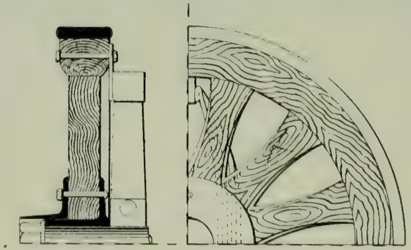


Fig. 19 *Simpson-Bodman.*

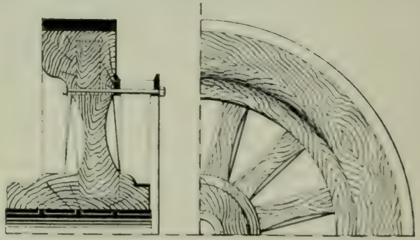


Fig. 20. *Coulthard.*

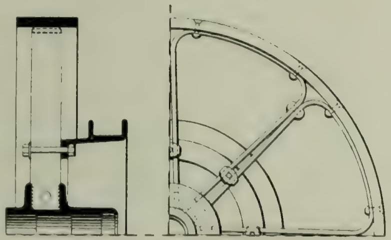


Fig. 21. *Simpson-Bodman.*

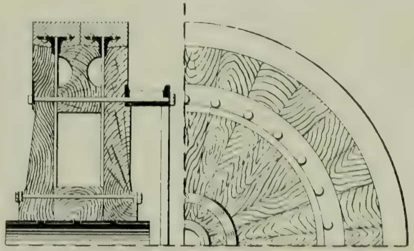
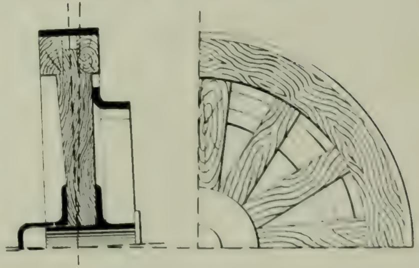


Fig. 22. *Bayley.*



Mechanical Engineers 1900.

Modification of the Ackermann System for Steering Motor Vehicles.

Fig. 23. *Daimler and others.*

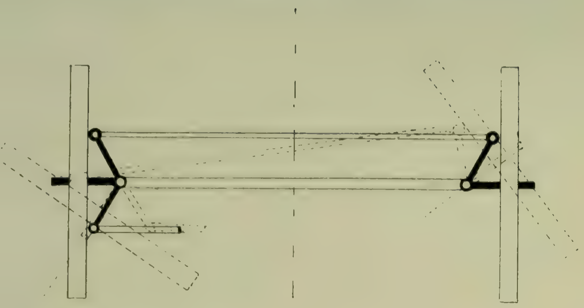


Fig. 24. *Clarkson & Capel and others.*

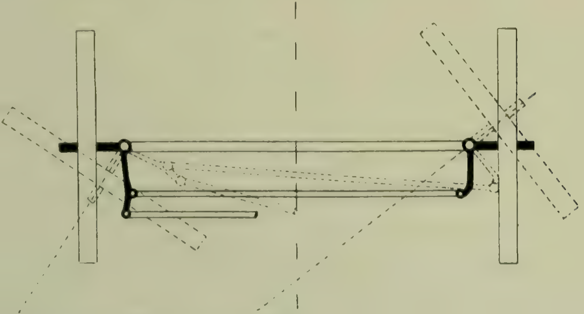
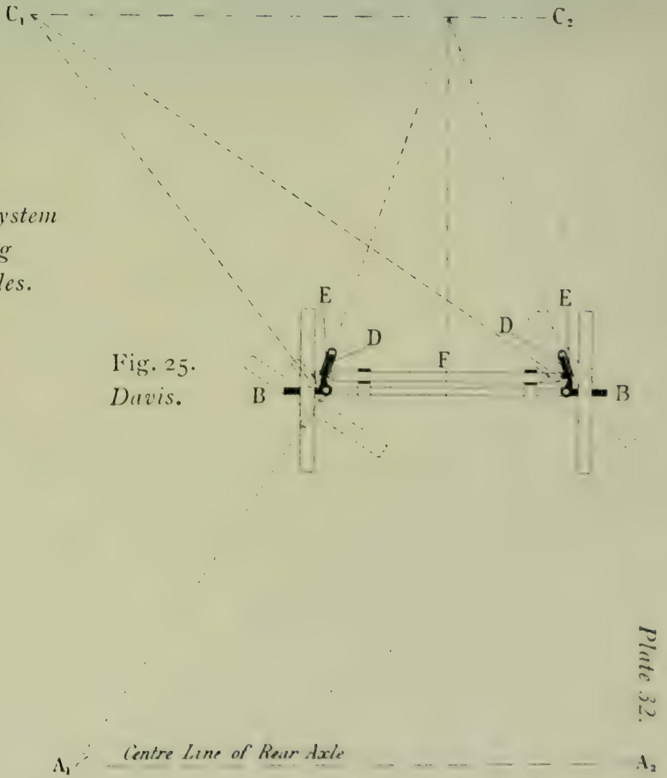


Fig. 25. *Davis.*



Balancing Vehicle Motors.
(Internal Combustion Engines.)

Fig. 26. *Prétot and others.*

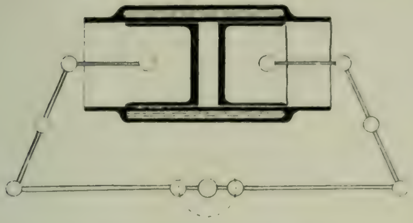


Fig. 27. *Gobron and others.*

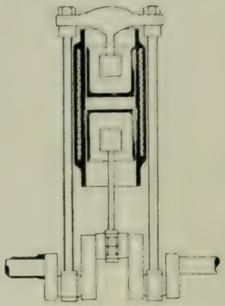
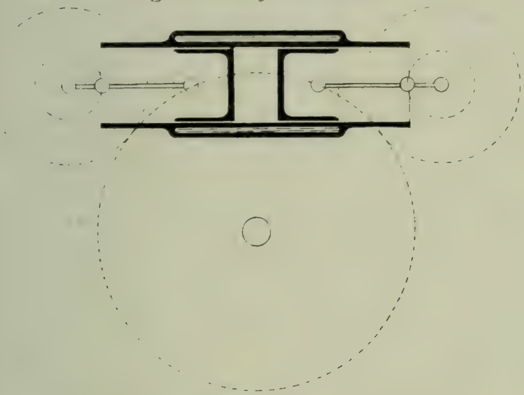


Fig. 28. *Hyler-White.*



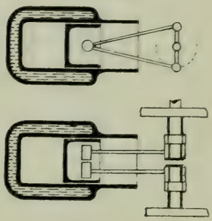


Fig. 29. *Lanchester, No. 1.*

Elevation.

Plan.

Fig. 30. *Henriod.*

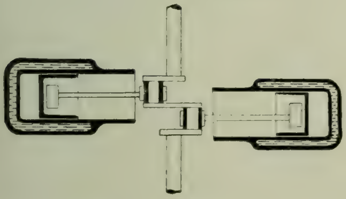


Fig. 31. *Lanchester, No. 2.*

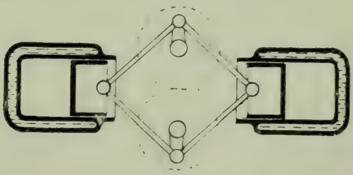


Fig. 32. *Daimler.*

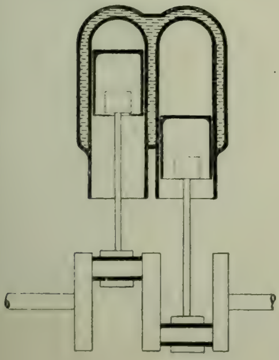
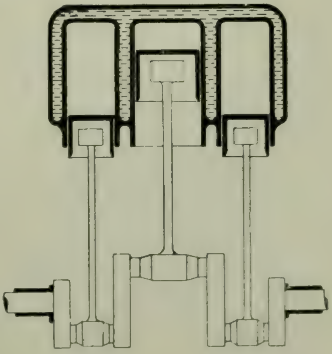


Fig. 33. *Monarch and others.*



Types of Heavy Motor Vehicles.

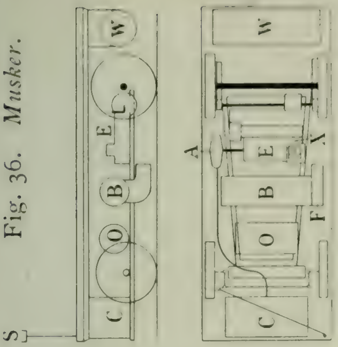


Fig. 36. *Musker.*

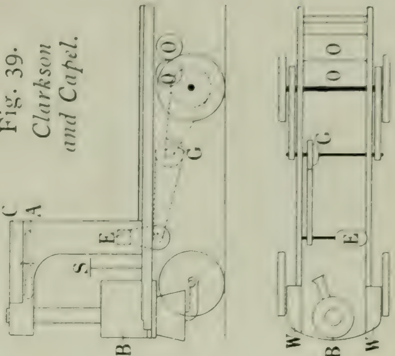


Fig. 39. *Clarkson and Capel.*

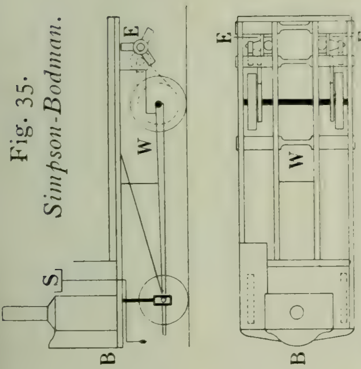


Fig. 35. *Simpson-Bodman.*

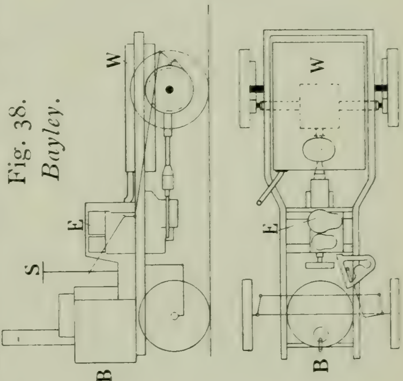


Fig. 38. *Bayley.*

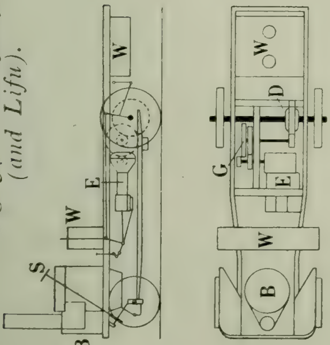


Fig. 34. *Thornycroft (and Lifu).*

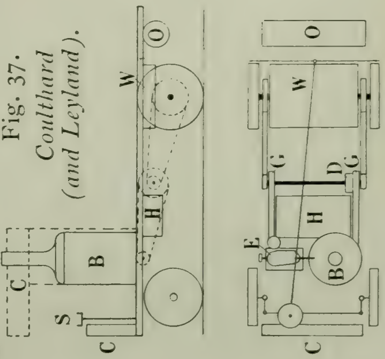


Fig. 37. *Coulthard (and Leyland).*

A. *Air Fan.* B. *Boiler.* C. *Condenser.* D. *Differential Gear.* E. *Engine.* F. *Funnel.* G. *Gearing.*
H. *Hot-water Tank.* O. *Oil Tank.* S. *Steering.* W. *Water Tank.* X. *Auxiliary Engine.*

Types of Burners used for Motor Vehicles.

Fig. 40. *Longuemare.*

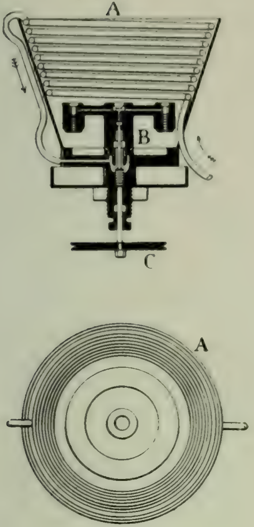
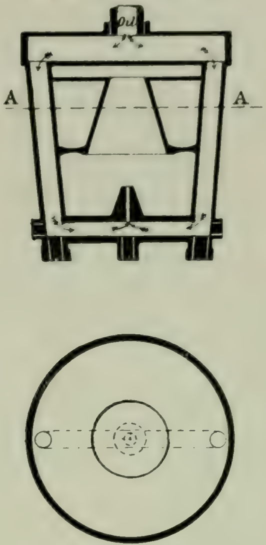


Fig. 41. *Leyland.*



Section on AA.

Fig. 42. *Lifu.*

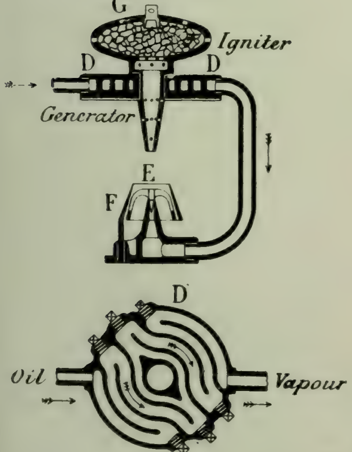


Fig. 43.
Locomobile or Stanley.

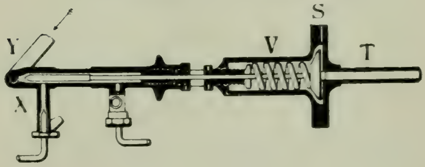
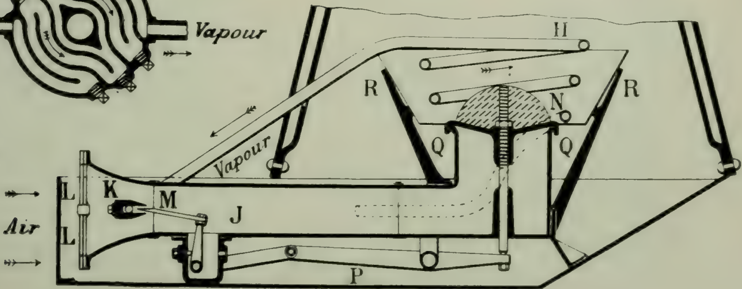


Fig. 44.
Clarkson and Capel.



Mechanical Engineers 1900.

Steam Generators, Water-Tube Types.

Fig. 45. *Thornycroft.*

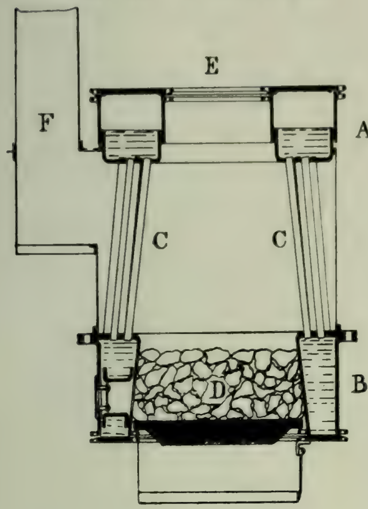


Fig. 46.

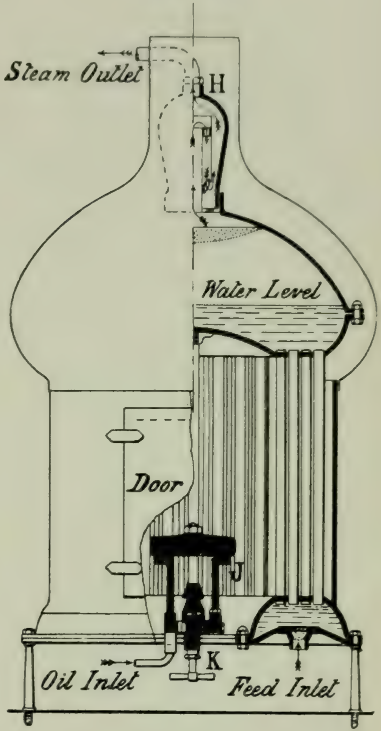


Fig. 47. *Merryweather and Clarkson & Capel.*

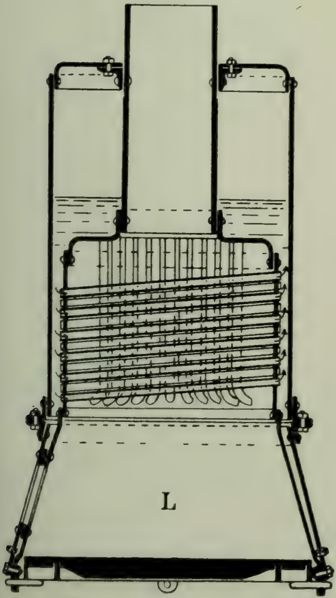
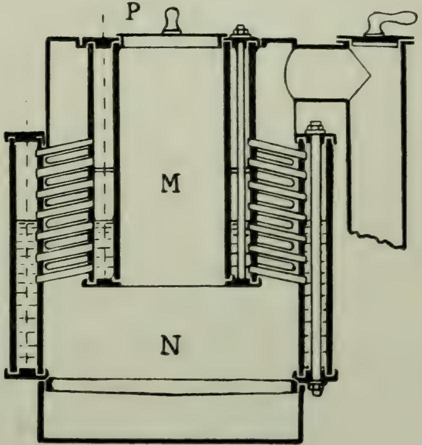


Fig. 48. *De Dion.*



ROAD LOCOMOTION.

Steam Generators, Flash Types.

Fig. 49. *Serpollet.*

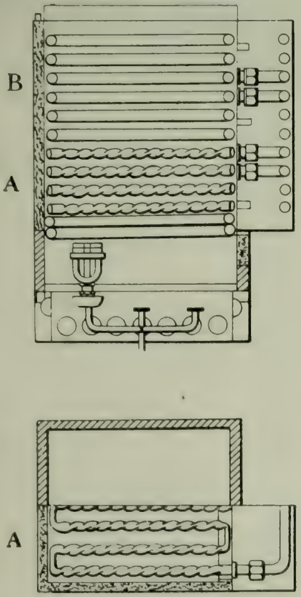


Fig. 50. *Simpson-Bodman.*

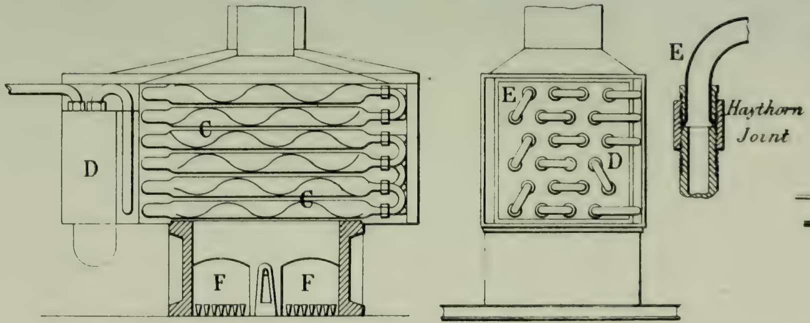


Fig. 51. *Tangye.*

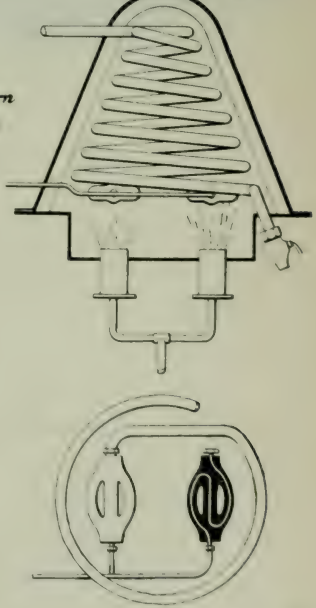
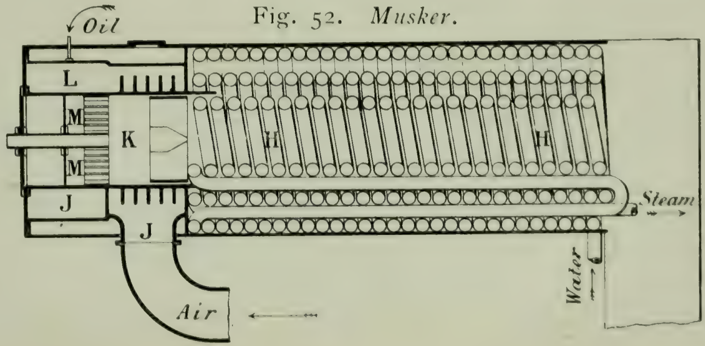


Fig. 52. *Musker.*



Mechanical
Engineers 1900.

Plate 37.

Elliott & Fry.

E. Windsor Richards

PRESIDENT, 1896-97.

Brown's "Viagraph."

(Mr. Barr's Communication)

Fig. 54. Elevation.

Fig. 55. Plan.

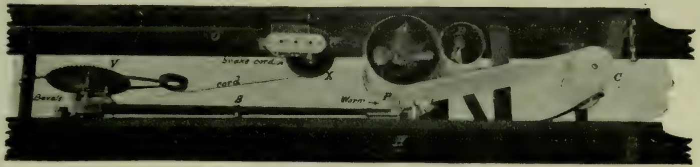
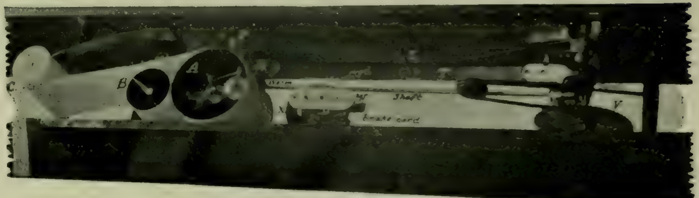
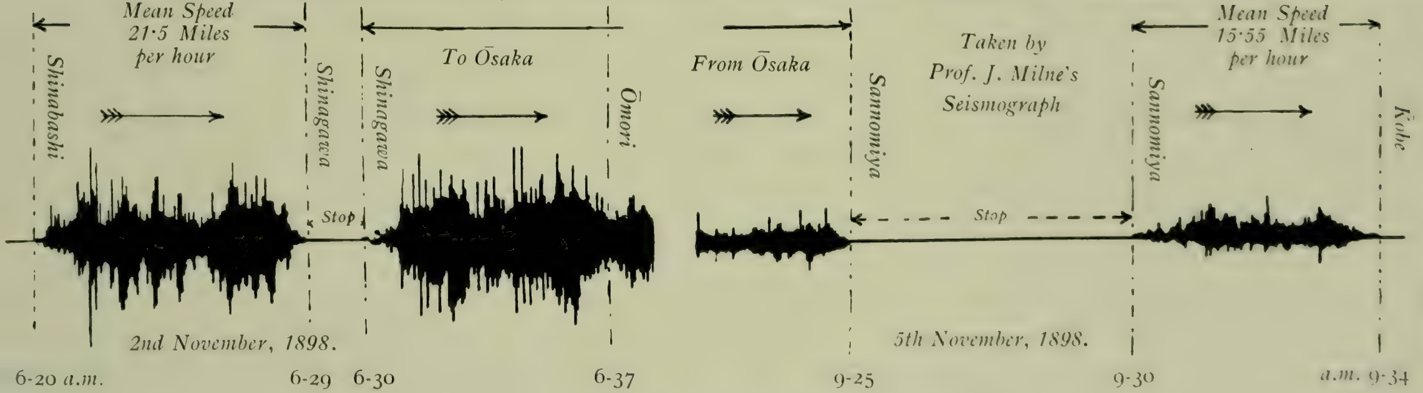


Fig. 56. Plan.



(Prof. Milne's Communication)

Fig. 57. Vertical Vibrations (full size) on Japanese Government Railway.



THE INSTITUTION

OF

MECHANICAL ENGINEERS.

ESTABLISHED 1847.

PROCEEDINGS.

1900.

PARTS 3–4.

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STOREY'S GATE, ST. JAMES'S PARK, WESTMINSTER, S.W.

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* "Power-Gas and large Gas-Engines"; by H. A. Humphrey (*see Proceedings* 1901, *Part* 1).

PAST-PRESIDENTS.

George Stephenson, 1847–48. (*Deceased* 1848.)

Robert Stephenson, F.R.S., 1849–53. (*Deceased* 1859.)

Sir William Fairbairn, Bart., LL.D., F.R.S., 1854–55. (*Deceased* 1874.)

Sir Joseph Whitworth, Bart., D.C.L., LL.D., F.R.S., 1856–57, 1866. (*Deceased* 1887.)

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James Kennedy, 1860. (*Deceased* 1886.)

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Robert Napier, 1863–65. (*Deceased* 1876.)

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Sir Frederick J. Bramwell, Bart., D.C.L., LL.D., F.R.S., 1874–75.

Thomas Hawksley, F.R.S., 1876–77. (*Deceased* 1893.)

John Robinson, 1878–79.

Edward A. Cowper, 1880–81. (*Deceased* 1893.)

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Jeremiah Head, 1885–86. (*Deceased* 1899.)

Sir Edward H. Carbutt, Bart., 1887–88.

Charles Cochrane, 1889. (*Deceased* 1898.)

Joseph Tomlinson, 1890–91. (*Deceased* 1894.)

Sir William Anderson, K.C.B., D.C.L., F.R.S., 1892–93. (*Deceased* 1898.)

Alexander B. W. Kennedy, LL.D., F.R.S., 1894–95.

E. Windsor Richards, 1896–97.

Samuel Waite Johnson, 1898.

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1900.

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E. Windsor Richards,	Caerleon.
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Harry Lee Millar.	Robert A. McLean, F.C.A.

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Edgar Worthington,
The Institution of Mechanical Engineers, Storey's Gate, St. James's Park,
Westminster, S.W.

Telegraphic address:—*Mech, London.* Telephone:—*Westminster*, 264.

The Institution of Mechanical Engineers.

PROCEEDINGS.

June 1900.

The Summer Meeting opened at the Institution on Wednesday, 27th June 1900, at Half-past Ten o'clock a.m. The chair was taken by Edward P. Martin, Esq., Vice-President, in the absence of the President, Sir William H. White, K.C.B. The President, Mr. Charles H. Morgan, and a considerable number of Members of the American Society of Mechanical Engineers were present.

The Chairman, in welcoming the President and Members of the American Society of Mechanical Engineers, regretted that ill-health prevented Sir William White from being present that day to receive them himself. As one of those fortunate English engineers—and there were several present—who had had the privilege about ten years ago of enjoying hospitality on the other side of the water, he was there that day to gratefully acknowledge their debt, endeavouring to show that they, the English engineers, did not forget. He well remembered the hearty greeting of Mr. Carnegie, whose words, "Welcome, welcome, thrice welcome to our guests" seemed to him very suitable to the present occasion. He ventured to add that they were receiving them as friends as well as guests—not as strangers. In coming to London he was sure they felt that they were really at home, and they would find that feeling much stronger on their return from visiting that wonderful Exhibition of our friends and neighbours on the other side of the Channel. They would on their return to this country find they had made a long step back towards home. Having

(The Chairman.)

welcomed them with these few words he would call on Mr. E. Windsor Richards, Past-President of this Institution and Past-President of the Iron and Steel Institute, a gentleman who was as well known and as much appreciated on their side as he was on this, to add a few further words of welcome.

Mr. E. WINDSOR RICHARDS, Past-President, said it gave him very great pleasure to respond to the invitation of the Chairman to say some words of welcome to the American Engineers, for he had heard many kindly expressions on many occasions from their American engineering friends, when he had been on the other side of the Atlantic. He trusted that every advantage would be taken of the present occasion to exchange views on engineering subjects generally, and above all, that they all would make new and lasting friendships. On behalf of the Institution of Mechanical Engineers, and on his own behalf, he re-echoed the words of the Chairman, and bade them a most hearty welcome.

Mr. CHARLES H. MORGAN, President of the American Society of Mechanical Engineers, said that he joined in regrets for the ill-health of Sir William H. White, and the hope for his speedy recovery. They felt highly honoured in receiving the greetings of generous welcome from this Institution in their beautiful house, which had so many names of eminent engineers enrolled upon its list of members. He sincerely hoped that their friendship might grow broader and deeper, that they might encourage and stimulate each other in their noble profession as engineers, and they extended to the Members of the Institution a most hearty welcome to the United States.

The Minutes of the previous Meeting were read, approved, and signed by the Chairman.

The Chairman announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and the following sixty-five candidates had been found to be duly elected:—

MEMBERS.

Allen, Richard William,	Bedford.
Atkinson, Frederick Arthur,	London.
Cutler, Arthur Edward,	Sydney.
Douglas, James McDonald,	Beira.
Dunlop, Peter,	London.
Eastwood, William,	Bradford, Yorks.
Feak, William Mark, R.N.,	London.
Fowler, Alexander Farquharson,	Preston.
Hambly, John,	Port Elizabeth.
Harris, Lloyd Price,	Bedford.
Hattersley, Robert Lund,	Manchester.
Hawksley, Kenneth Phipson,	London.
Humphreys, Henry Howard,	London.
James, Charles, Jun.,	Grantham.
Jones, Walter,	Stourbridge.
Knowles, John,	Bombay.
Markham, Reginald Gascoigne Law, R.N.,	Mediterranean Squadron.
Marshall, Alfred William,	London.
Nicholl, John Jeffery,	London.
Robinson, Edward Mark,	London.
Smith, William Hill,	Bradford, Yorks.
Thompson, George William,	London.
Wingfield, Charles Humphrey,	London.
Wright, Benjamin Hollingworth,	London.

ASSOCIATE MEMBERS.

Asquith, William George,	Bradford, Yorks.
Baldwin, Christopher Edmund,	Darlington.
Britten, Thomas,	Wolverhampton.

Bull, Rowland Francis,	London.
Bull, Thomas Palmer,	London.
Coleman, Cecil Edward Ogilvy,	Redditch.
Crawford, John Forcer,	Liverpool.
Cruickshank, George Seymour,	Kalgoorlie.
Darker, Alfred Henry,	London.
Davis, Harry Charles,	London.
Dresser, Charles,	London.
Hicks, Fredrick George,	Guernsey.
Infante, Pasquale,	London.
Lund, Harry,	Keighley.
Parker, Frederic George William,	London.
Parkinson, Ernest,	Shipley, Yorks.
Riches, Carlton Tom Hurry,	London.
Rosevere, Reginald George,	Derby.
Simpson, Donald Grafton,	Barbados.
Smith, Frederick Hardcastle,	Leeds.
Squire, George Frederick,	London.
Taylor, Charles Percy,	Northfleet.
Townsend, William,	London.
Venning, Thomas Arnold, R.N.,	China Station.
Woodhouse, William Bradley,	London.

ASSOCIATE.

Leonard, Robert Maynard,	London.

GRADUATES.

Appleby, Thomas Darby Haslam,	London.
Cowcher, George,	London.
Deacon, Robert Dugald,	Rio de Janeiro.
Dyson, John Daniel,	Bradford, Yorks.
Forward, Ernest Alfred,	London.
Hedley, William Scott,	Spennymoor.
Heydemann, Harry George Julius,	Maritzburg.
Horsfield, Percy Firth,	Dewsbury.
Lenox, George Duncan,	Kilmarnock.

Minors, Ernest,	Wolverhampton.
Perry, Edgar William Frank,	London.
Plante, Stanley Gedge,	London.
Robertson, Walter Henry Antonio,	London.
Smith, Walter Tom,	London.
Viney, Horace,	London.

Transferences.

The Chairman announced that the following four Transferences had been made by the Council since the last Meeting :—

Associate Members to Members.

Iden, George,	Coventry.
Pullar, Albert Evans,	Perth.
Umney, Herbert William,	London.

Graduate to Associate Member.

Chatwood, Arthur Brunel,	London.

The Discussion on Professor Hele-Shaw's Paper on "Road Locomotion," which had been adjourned from the April Meeting, was resumed; and a short supplementary Paper dealing with the recent 1,000 Miles Road Trials was read by Professor H. S. Hele-Shaw, LL.D., F.R.S., *Member*, of Liverpool. (The whole was published in Part 2, pages 185–321.)

At One o'clock the Meeting was adjourned to the following morning.

The Adjourned Meeting was held at the Institution on Thursday, 28th June 1900, at Half-past Ten o'clock a.m.; Edward P. Martin, Esq., Vice-President, in the chair.

The following Papers were read and discussed :—

"Notes on the construction of 'Long Cecil,' a 4·1-inch rifled breechloading Gun, in Kimberley, during the Siege 1899–1900"; by Mr. EDWARD GOFFE, *Associate Member*, of Kimberley.

"Recent Locomotive Practice in France"; by M. EDOUARD SAUVAGE, *Member*, Assistant Engineer-in-Chief, Rolling Stock and Running Department, Western Railway of France.

"Polyphase Electric Traction": by Professor C. A. CARUS-WILSON, of London.

The remaining two Papers announced for reading and discussion were postponed.

The CHAIRMAN proposed the following Votes of Thanks, which were seconded by Mr. HENRY D. MARSHALL, Member of Council, and passed with applause :—

To the Reception Committee, and especially to the Executive Sub-Committee, for the excellent arrangements they have made for the conduct of the Meeting and the entertainment of the American Visitors.

To the Authorities and Proprietors of the various Engineering and Manufacturing Works and other Establishments visited by the Members, for their kindness in opening their Works during the Meeting.

On the motion of Mr. JAMES STABLER, a hearty vote of thanks was unanimously accorded to Mr. Martin for presiding in the absence of Sir William White.

The Meeting then terminated at One o'clock. The total attendance at the Meeting, including the several functions, was 545 Members and 80 Visitors.

NOTES ON THE CONSTRUCTION OF "LONG CECIL," A 4·1-INCH RIFLED BREECHLOADING GUN, IN KIMBERLEY, DURING THE SIEGE 1899-1900.

By Mr. EDWARD GOFFE, *Associate Member*, of Kimberley.

The object in view was to make a gun of greater power than those possessed by the garrison, which were 2·5-inch R.M.L. guns (7 pounders), and were not big enough to effectually reply to the enemy's 15 pounders, or to make any impression on his works.

A gun of about 4 inches bore, firing a shell 25 lbs. to 30 lbs. weight, appeared to meet the case, and to be possible of construction.

The possession of a billet of hammered mild steel (originally intended for shafting and ordered as such), 10½ inches diameter and 10 feet long, made by Messrs. Sybry, Searls and Co., of the Cannon Steel Works, Sheffield, and of several bars of 6-inch by 2½-inch Low Moor iron, in the workshops of the De Beers Consolidated Mines, really suggested to the late Mr. George Labram, chief engineer to the Company, the possibility of making the gun, by boring the steel bar to form the tube, to be strengthened by rings shrunk on, made of the Low Moor iron. The makers of the billet subsequently wrote that the steel, from which the inner tube was constructed, was originally intended for shafting, and was considerably lower in carbon than they would supply for the purpose of making gun barrels. Tensile tests from this steel would have resulted somewhat as follows:—27 to 30 tons per square inch breaking strain, with 20 to 35 per cent. elongation in a length of 8 inches, with 40 per cent. reduction of area.

The resulting gun would evidently be of a type similar to an early "Armstrong," heavy for the work done compared with one of a more modern type, but in this case weight was a minor point to be considered, ease and quickness of manufacture being perhaps the leading ideas.

The first difficulty met with was the resistance of the military authorities to the attempt to make the gun, but as this was hardly a mechanical difficulty, further reference to it may be out of place. However, on Christmas Day 1899, Mr. Rhodes, Chairman of the Company, gave the order to Mr. Labram to make the attempt. Work was immediately started, and then the difficulty consequent on ignorance, on the part of both Mr. Labram and the author, of practical gun design, was first met with. This was overcome by a search in all books available, and the scattered information so obtained brought together. The sources of information were:—The articles on Gunnery, &c., in the Encyclopædia Britannica; the Military Treatise on Ammunition (which had been previously used in gaining information to make shells and cartridges for the 2·5-inch guns earlier in the siege); Articles on Modern Guns in "Engineering," &c.; and from the military "Text Book on Gunnery," brought forward by an enthusiastic volunteer officer, and which proved very serviceable. During the progress of the work in the shops, assistance was also given in many details of gun-shop practice, the form of special tools used, &c., by several of the employées there, whose previous experience in Woolwich Arsenal, the Elswick works, and elsewhere, was willingly given to forward the work in hand.

Approximate calculations only were made, for two reasons, one that it was not considered necessary to go into very fine calculations when the two principal factors, the powder pressure and the test strengths of the materials to be used, were not known, and could only be estimated, recourse being preferably made to comparisons of the performances of similar guns. The other reason was that time was pressing—the designing, and supplying of sketches going on simultaneously with the making of the gun in the workshops.

The stock of powder in the town was of many kinds, ranging from "mealed" to compressed cylinders $1\frac{3}{8}$-inch diameter by 2 inches long. Most of it had been kept for a long time, much of it over ten years for certain, but it did not appear to have deteriorated, still retaining a good glossy surface.

The cylinder powder (black) was evidently the most suitable for use, but there was not very much of it, so preparations were made to compress the finer powder into blocks, and so form a slower burning powder. The possibility of the compressing not being successful when the stock of cylinders was exhausted, and of having to use all kinds, had to be faced, but there proved to be sufficient cylinders to provide cartridges as long as the gun was fired.

From data available it appeared that 50,000 lbs. to the square inch would be a suitable maximum pressure to allow for, that being about the maximum pressure calculated, when using a charge of 5 lbs. of powder in the space which would be available for a powder chamber. But while using the slow-burning powder the shell presumably would begin to travel before that pressure was attained. Many charges of 6 lbs. were used while the gun was in action, the maximum pressure due to these conditions appearing to be about 90,000 lbs. per square inch, but for the same reason, probably the actual pressure reached would not much exceed that obtained from the use of the smaller charge.

A powder chamber of 4·25 inches bore it was found would just contain seven cylinders of powder, four of $1\frac{3}{8}$ inch diameter, and three of $1\frac{1}{8}$ inch diameter, their combined weight for 2 inches of length being just 1 lb. With this diameter of chamber, to obtain a normal air-spacing, the length required to be about 12 inches. Next the breech screw must necessarily be about $5\frac{1}{2}$ inches diameter, and allowing a length of thread equal to $1\frac{1}{4}$ diameters and about 2 inches for obturator, the length of the breech block would be, say, $10\frac{1}{2}$ inches. The total length of the steel billet was 10 feet $\frac{3}{4}$ inch, so deducting from this 1 foot $10\frac{1}{2}$ inches, the length available for the bore was 8 feet $2\frac{1}{4}$ inches, very nearly 24 calibres in length.

Upon this basis the strength was next figured out, and the tube alone first taken. Using a formula for the strength of a thick tube subjected to 50,000 lbs. per square inch internal pressure, the greatest stress in the material was found to be 70,000 lbs. per square inch. This showed, as was expected, that the tube could not be used without shrunk rings.

By shrinking on two rows of rings, each 2 inches thick, a reduction of the greatest stress in the tube to about 40,000 lbs. per square inch, and that in the rings to 20,000 lbs. per square inch, was calculated, and this it was considered safe to allow. That there was sufficient strength was evident; but the author would like to know really what pressure was attained at any time, the only sign of strain being that the powder chamber has enlarged slightly and is now barrel shaped, the diameter at the centre being fully $\frac{1}{32}$ inch greater than as originally made. This is apparently due to direct compression of the metal, as the outside diameter was carefully gauged when an opportunity was given by some of the rings being removed, and was found to be exactly as made.

The order to make the gun was given on the evening of Christmas Day, 1899, and at the start of work next morning the billet of steel was taken into the machine shop. A lathe of 12 inches centre with bed 14 feet long was used, the extra length of bed required for working the boring bars and rifling gear being obtained by the use of the bed of a similar lathe set in line with it, with the headstock removed. This was already in position, being used when working on lengths of shafting, &c.

Most of the men required on the work had to be temporarily withdrawn from the redoubts where they were stationed, forming part of the Town Guard. During the building of the gun and making of ammunition, the workshops were always under fire from the enemy, many shells, including 94-pounders, bursting around and passing over the buildings, none however actually doing damage; but it was very trying for a man to stay at work at a lathe or other machine, hearing shells bursting around, and not knowing whether the next would come inside or not, and all those who had that experience deserve appreciative mention for the way in which they stuck to their posts.

Fig. 2, Plate 40, shows the general construction of the gun. The steel billet was first turned all over outside, a shoulder of $\frac{1}{8}$ inch being made to take the thrust of the trunnion ring, the largest diameter being 10·5 inches. It was turned tapering towards the muzzle, a parallel part about 9 inches long being left there to be used as a journal when boring. For boring, the breech end was held in a dog chuck with the muzzle revolving in a hard wood bearing, and first a twist drill $1\frac{1}{2}$ inch diameter put right through. This was followed by a twist drill 3 inches diameter, then the end counterbored with a tool and a boring bit, Fig. 7, Plate 41, started, enlarging the hole in one cut to $3\frac{15}{16}$ inches diameter. The bit was plentifully supplied with water through the bar, which was one belonging to a diamond boring drill. All went through without any special difficulty, but experience showed that the boring cut was too heavy, and it would have been better to have taken two cuts for that amount.

While this turning and rough boring were being done, which occupied about a week, the rings were being forged, nine being wanted for the first row, $10\frac{1}{4}$ inches diameter inside (less shrinkage), and four wanted for the outside row, about $14\frac{1}{4}$ inches diameter. These were all made from the 6-inch by $2\frac{1}{2}$-inch Low Moor iron, a length of bar being cut, bent to a circle, and the ends welded together. As these were finished they were passed on to the machine shop, where they were turned, faced, and bored to gauge.

The trunnion ring was a greater undertaking than the plain rings, and the difficulty of making a satisfactory weld in so heavy a piece of work, with the appliances at his command, was overcome by the leading blacksmith, by working it out of a length of 6-inch by 6-inch Low Moor iron, starting a small hole through the centre, and enlarging by successive heats until he had it to the required size for machining.

By the time the rings of the first row with the trunnion ring were made, the tube was ready to receive them. For shrinking, the tube was held vertically under a convenient derrick in the yard, first with breech end upwards. The ends of the bore were plugged, and a circulation of cold water arranged inside to keep the tube cool. The rings were heated on a plate over a wood fire, the bore being gauged until sufficient expansion was evident, then lifted by the derrick over the end of the tube and dropped into place, the trunnion ring being the first to go on, resting against the shoulder. As a precaution against possible travel endways while cooling, each ring was clamped by longitudinal bolts, and the adjoining one on which it rested kept cooled down by a stream of water from a hose pipe. The tube was reversed to put on those rings in front of the trunnions, and, the whole of the first row being in place, it was returned to the lathe, and the outside of the rings turned up to form a seating for the second row over the powder chamber. The process of shrinking these was the same as for the first row, and when they were on, the barrel was again returned to the lathe for finishing.

The final boring was then begun, the tool used being a studded bit with double-ended cutter, Fig. 8, Plate 41.

Meantime, the question of rifling had been gone into, and, the increasing twist appearing more desirable and easier on the gun than the uniform twist, it was decided to make it so. To effect this the rifling attachment, as shown in Fig. 6, Plate 41, was devised, the idea being given to the author by remembering one of Sir W. Anderson's lecture diagrams. The author has since learnt this method is still used in gun factories. The drawing shows a channel-iron bolted to two cross channels, which are bolted to the ends of the lathe bed. On this channel-iron the developed curve of the spiral—a semi-cubical parabola—was set out by its ordinates. A planed bar to act as a forme was bent to the curve, and screwed down with countersunk screws. The hardwood blocks, forming the guides to the rack, and bearings for the rifling bar, were bolted solidly together and to the saddle of the lathe. The end of the rack (which was a stock one as used on the washing machines) is furnished with one little roller, travelling on the "forme" bar, contact being kept by a cord attached to the underside of the rack, carried over a pulley at some distance and having a weight at the end. A small guide pulley should be shown on the saddle to allow for vibration of cord with travel of saddle. The traversing of the saddle was done by the leading screw of the lathe, a small belt pulley being put on in the place of the usual "change" wheel, with a belt from the overhead drive.

A detail of the rifling head $\frac{1}{10}$th full size, is shown, Fig. 9, Plate 41. It was formed of a solid block of steel, turned to fit the bore of gun, into which the end of the rifling bar was tightly screwed. The tool was able to revolve slightly on its pin as a centre, being kept up to position by the set screw and packing block, which also regulated the depth of the cut taken, while clearance on the return stroke was possible by the giving of the spring. A felt pad held by a washer was attached to the head in front of the tool, while the head drew another wad of felt behind it, to clean the bore of cuttings as made, and a supply of soapy water under pressure was forced in behind the head, the two semicircular grooves being provided to allow the supply to get to the cutting edge. The only serious trouble experienced in the workshop processes was at this point, when it was found most difficult to get the tool to cut properly, and a lot of time was spent in trying to find the reason, three grooves only being got through between about ten o'clock one morning and late the following night. The material could not be at fault, as it had been found perfectly good, without flaws, and very clean cutting up till then, and new tools and different lubricants were tried, but with no success, until the packing block, which took the pressure of the tool, and which consisted of a small piece of iron, was noticed to be denting, when a new one of cast steel hardened was put in its place, and no further trouble was experienced, the remaining twenty-nine grooves being finished in about eight hours from then.

The rifling was started from the extreme end of the barrel at the breech, so that there was about 2 feet of length to spare, to be afterwards bored out for breech and powder chamber, so that should a false start have been made with a groove by accident, no damage would have resulted. After rifling, the bore was lapped out to take off any roughness left by the tool, and then reversed in the lathe and the powder chamber bored out, a double-ended tool similar to that shown by Fig. 8, Plate 41, being used.

The breech-block screw having meanwhile been made, the inside was cut, and the block fitted in. In cutting this thread in the barrel, the question of the ending of the cut inside had to be met, and the simplest way seemed to be to let the tool finish in a clearance hole, and to drill this hole inside: the little drilling machine, Fig. 10, Plate 41, was made, being worked by a gut band from a convenient source of power.

The breech-block and obturator are shown in detail in Figs. 3, 4 and 5, Plate 40. The De Bangé system of obturation was adopted, that appearing to be the most efficient and easily made. The obturator pad was made of rings of sheet asbestos soaked in melted tallow, and proved quite successful. The breech-block as made first and used with radial firing is shown in Fig. 3. The block was of hammered mild steel, the same material as the tube of the gun, screwed with a V thread of $\frac{3}{4}$ inch pitch with flattened top and bottom. The handle-bars and plate are one forging, fastened to the screw with six tap bolts. The obturator bolt with mushroom head was made of mild steel, $1\frac{1}{2}$ inch diameter shouldered near the middle to $1\frac{1}{4}$ inch diameter, and held by lock nuts in a recess at the back. As thus made about 100 rounds were fired with this obturator. Figs. 4 and 5 show it as subsequently made, the reasons for which alterations will be described in due course.

It was arranged originally to have an interrupted screw, cut away in three sections, so that one-sixth of a turn of the handle-bar would release the breech-block; but consideration of the time to be saved by not cutting it, which it was thought would be at least two days, and the further consideration of strength, induced the author to urge keeping the screw intact, the actual extra time taken in unscrewing the whole way being only a few seconds.

With the interrupted screw, a safety-vent closing device was necessary, and one was made. One handle, as turned to unscrew the block, moved a plate sliding on the end of the barrel, which by means of a pin working in a diagonal slot closed the vent with a light plate, the reverse action taking place when the handle was turned to screw up the breech, so that the vent could only be open when the breech was tight. With the plain screw this was not so urgently required, and although the guard over the vent was retained for a time, it was not used. The vent hole was drilled in the gun barrel after the powder chamber was bored and the breech fitted, and was $\frac{3}{4}$ inch diameter. About an inch at the top was tapped with $\frac{1}{2}$-inch gas thread, and a copper plug fitted as tightly as possible for the whole length being screwed at the end to fit the hole. This copper plug had a small hole drilled through it to fit the friction tubes used.

A relieving hole $\frac{1}{2}$ inch diameter was also drilled through the underside of the barrel from just behind the obturator, to prevent any damage to the thread from the product of explosion, should the obturator ever act imperfectly. But at no time during firing was any smoke noticed coming from it. A flat place true with the axis of gun was planed on the top for standing a clinometer upon. A gun-metal casting bolted to the underside was cup-shaped to fit the end of elevating screw, which was turned to a ball. This it was found necessary to replace by a hinge joint, as the gun jumped on firing, and the elevating screw when in an inclined position tended to fall over, and the cup did not come fairly on to the ball end. The back sight, copied from that of one of the 2·5-inch R. A. guns, was provided with a fine traverse for wind allowance, &c., and was set at an angle of two degrees from the vertical (to the right) to allow for "drift" of shell, which was found on firing to be almost exactly correct. The front sight on the trunnion was first made as a bead in a small tube, but was afterwards altered to a knife edge without the tube. This completed the gun itself, ready for mounting on its carriage, as first turned out of the workshops.

Carriage.—The carriage having been made in the meantime was ready for the gun. Its general construction is well shown in the accompanying photograph, Plate 39. It was formed of four steel plates $\frac{1}{4}$ inch thick, cut to shape, riveted together in pairs, $2\frac{1}{2}$ inches apart, with distance sleeves on the rivets, and with gun-metal castings also acting as distance pieces and riveted in, for trunnion and axle bearings. The two pairs of plates were bolted together with shouldered bolts, $17\frac{1}{4}$ inches apart, and with a rubbing plate at the trail end, which was also provided with an eye bolt for hanging to limber. The elevating screw was of steel, $2\frac{1}{4}$ inches diameter, with square thread $\frac{1}{4}$-inch pitch, working in a nut pivoted between the side frames, and provided with a hand-wheel. The axle was $4\frac{1}{2}$ inches diameter keyed into the side frames.

The wheels were the only part not actually made, and they were a pair belonging to a portable engine and suited the purpose admirably. They were bored out, had gunmetal bushes driven in bored to fit the axles, and brass dust-caps screwed on outside. The height of the centre of the trunnions from the ground is 5 feet. The centre of trunnions is 5 inches behind, and the point of contact of the trail with the ground 9 feet 6 inches behind, the vertical line through the axle, and the wheels are 5 feet centre to centre.

With twenty-four days of continuous work the gun was ready, and on the 19th January 1900 it was taken out for testing and ranging, a firing platform and redoubt having been built at No. 2 Washing Machine, Kimberley Mine Floors, whence the Boer headquarters (the Intermediate Pumping Station of the Kimberley Waterworks Co.) and several of their gun positions could be commanded. The ranging was done with the assistance of the Company's surveyors, one having a theodolite at the point of firing, while another, also with a theodolite, was stationed at a point about a mile distant, nearly at right angles to the line of fire. On firing each took observations of the spot the shell struck, and the angle of firing as shown by clinometer, time of flight, charge of powder, &c., also being observed and tabulated, the muzzle velocity was calculated, and range tables made for subsequent use, by Mr. C. D. Lucas. The back sight was not graduated for range, only being used for laying the gun, the firing party preferring to use the clinometer. The enemy appeared much disturbed when the first shells burst in their headquarters, and could be seen hurrying out in all directions, not expecting that they could be reached there, and there was no reply from any gun of theirs during the ranging trial. Mr. Rhodes was present the whole time and personally fired most of the shots, being very pleased with the performance of the gun, and the artillerists working it also were well satisfied with its shooting qualities. The trials having been completed, the gun was returned to the workshops for one or two minor alterations, including a new front sight and altered attachment for elevating screw, as already mentioned. These having been completed, the gun was handed over to the firing party and was in action on the 23rd January.

While in action 255 shells were fired in all by it, most of them being at ranges of 5,000 and 6,000 yards, these being reached with elevations of 12° and 15° respectively, with a powder charge of 5 lbs., the shell being 29 lbs. in weight. With the same charge a range of 8,010 yards was reached with an elevation of 24° 15′.

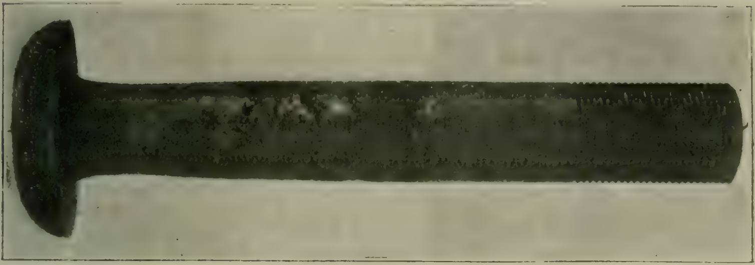
Ammunition.—It will be convenient here, before mentioning some further and serious difficulties experienced while the gun was in action, to describe the ammunition. The powder used has already been described. A good wool serge was chosen for the bags to form the cartridges, and they were made by a local draper, being hooped with silk ribbon. The "Ring" shell is shown in Fig. 11, Plate 42. The "Common" shell was similar, the only difference being in the absence of the rings cast in. Both kinds were used, their weight when filled with the bursting charge of 1 lb. powder being exactly 29 lbs. In making the shell the rings were first cast separately, then were mounted on a clay core, alternating tooth and space as will be noticed, the shell bursting better when thus arranged. This clay core with rings was then used as an ordinary core in the mould, and the metal poured. At first it was tried to cast them with the base solid, the core at that end supported by a "star," but this was not successful, the base being spongy in nearly every casting. Other methods were tried, and that adopted was to core them right through the base, that being downwards, and to pour in at a point about one-third the height from the end. Sound castings resulted. The cored hole in the base was plugged with a brass plug screwed in tight, and before issuing for service every shell was tested by steam at a pressure of 125 lbs. per square inch to detect blowholes, but none failed at that test, and no "prematures" were complained of. The shells after casting were turned to gauge, the point screwed for the fuse, and grooved for the copper gas-check, that being made from a ring turned and cut off to width required, then cut through with a saw, sprung into place and expanded into the dovetailed groove, afterwards being turned, and the relieving grooves cut. The insides of all shells were lacquered.

The percussion fuse was devised by Mr. Labram, his idea being to have the simplest possible one to make. The action of it is, that when the shell strikes and its forward motion checked suddenly, the plunger, which is filled with mealed powder, continues its motion forward, its impetus being sufficient to overcome the resistance of the safety spring and wires. The nipple strikes and explodes the cap, which is an ordinary percussion cap as used in sporting shot guns, the mealed powder is ignited and fires the charge in the shell.

It may be mentioned in passing that ammunition, both cartridges and shells—"common" and "ring"—had been made in the workshops and supplied to the garrison since early in November, for their 2·5-inch R.M.L. guns, the Government supply having been exhausted in about a month. This 2·5-inch shell is shown in Fig. 12, Plate 42.

From the time of its being handed over to the firing party on the 23rd January, the gun was fired steadily, the only trouble being a tendency for the end of the breech block to "upset" and get too tight in the screw. This was easily remedied by first easing the thread and subsequently removing one and then two threads at the end. On Saturday night firing ceased as usual, Sunday being observed as a day of rest—from gun-firing—by the Boers. But at daybreak on Monday morning the first shot fired by "Long Cecil" was productive of an extra loud and peculiar report, and the idea that something had gone wrong was general. A telephonic message came from the redoubt immediately afterwards and an examination showed that the second ring in the outer row had burst through the line of the vent hole. The gun was at once sent down to the workshops for repair. To take off the first ring the foundry cupola was lighted, the gun hung from the crane with the breech in the sand, and a ring of metal run round the first ring which in two or three minutes expanded and dropped off, releasing also the broken one, to replace which a forging was already in hand. On removing the gun from the sand a further examination showed that the two rings of the first row immediately under the outer broken one were also broken, these having broken straight across on alternate sides of the gun, Fig. 2, Plate 40. To remove these necessitated a repetition of the process, one more outer ring—the third, and the first inner ring having to be expanded. New forgings were put in hand, and opportunity was taken then to make a careful examination of the tube, but no flaw or crack of any sort could be detected, nor any change of dimension beyond the slight barrelling of the powder chamber already mentioned, which does not seem to have increased with subsequent firing. The cause of the failure was not at all evident. Faulty welds were the first things looked for, but in vain; and although in the outer ring one part of the broken surface looked as if it might be an imperfect weld, in the two others there was no mark whatever, and no sign anywhere by which to trace the position of the weld. The outer ring had certainly broken through the vent hole, and from marks on the rings which appeared to be powder-smoke stains, the conclusion was come to that the radial venting was the cause. The copper vent tube not being tight enough to withstand the great pressure, had allowed the gases to travel around it, and get under and between the rings, bursting them by direct pressure; and this action was assisted by a combination of favourable circumstances, namely, firing a 6-lb. charge of powder for the first shot in the morning, after the gun had been exposed to the cold air of the night, when the metal might be expected to be less tough than ordinarily. The outer ring was also weakened by having the vent hole through it, with the possibility of the weld happening to be at the same spot. The radial venting was condemned, and the breech prepared for an axial vent, experiment being first made to see whether the "friction tubes" would strike through the distance necessary which it was found they would do easily. The vent hole in the gun tube was tightly plugged, and the new rings when ready shrunk on. No alteration was made in the breech block beyond boring the vent hole through the obturator bolt, and providing a safety device to prevent the friction tube blowing out behind and possibly injuring some person. These alterations, as shown in Fig. 4, Plate 40, having been completed, the gun was taken out to the redoubt again and put in action, but at the first shot under the new conditions, the obturator bolt (the same one as had been used all the time, and with which about 100 rounds had been fired) broke as shown in Fig. 4. A spare breech block had already been prepared with the obturator bolt increased in size to 2 inches diameter without shouldering, and the end brought right through the back plate, but at the first shot this one also broke off short under the mushroom head, and it was beginning to be an anxious time to know what to do to make something which would stand the shock, when one of the fitters let out that he had known a time at Woolwich when six or seven similar bolts had broken with successive shots—which statement somewhat relieved the anxiety—and he further suggested annealing in oil as an expedient which might help. This was immediately done, several bolts being made for emergencies, but none broke after that. The obturator bolts were made from ordinary rolled shafting 4½ inches diameter. One obturator bolt was made from cast steel 2½ inches square, the end being "jumped up" until of sufficient size to turn to the diameter required, but not tooled at all by the smith. This bolt was annealed as the others in melted tallow before finishing, but was not used. The present breech block is shown by Fig. 5, which also shows the peculiar drawing-down action taking place in these bolts. Three of them were used with two breech blocks from that time until the 15th February, when Kimberley was relieved, about fifty rounds being fired by each bolt. The only way to account for the action seems to the author to be that the shock of the explosion drives the whole bolt back, compressing the asbestos pad. Then on the relief from the pressure, the pad expands again, tending to bring the bolt back to its original position, which is opposed by the inertia of the body of the bolt, causing a tensile stress in the bolt which is sufficient to cause permanent set at the point where the greatest stress comes, close to the head. A photograph of one of the bolts is shown in Fig. 13.

FIG. 13.—*Obturator Bolt,*
made from ordinary rolled shafting 4½ inches diameter.



Kimberley was relieved before any further difficulties arose, and the gun is now resting, waiting for its next position, which it is expected will be in a prominent position in the town, forming part of a monument to the memory of those who fell in the defence of Kimberley, and chiefly of him who originated it—George Labram—who, by his great mechanical skill and general resourcefulness in all matters, contributed in no small degree to that end, and who was most regrettably killed only a few days before relief came.

The Paper is accompanied by a number of blue prints and photographs, from which the four Plates, Nos. 39–42, have been prepared.

Discussion.

The CHAIRMAN said Mr. Goffe was not present. The Paper recounted a piece of very remarkable work done under most remarkable circumstances, but it was not intended to have a long discussion upon it owing to Mr. Goffe's absence. Mr. H. F. Donaldson, of Woolwich, who was present, would perhaps make a few remarks.

Mr. H. F. DONALDSON said he had not come prepared to make any remarks at all. At the same time it was a great pleasure to him to bear witness to the skill, the initiative, and to the success which met the efforts of Mr. Labram. Mechanical engineers worked best in peace, but when circumstances called upon them requiring special effort, it was a matter of congratulation that someone was generally there to take hold of whatever there was possible of manipulation, and turn out excellent results. He thought it was really wonderful, because so far as he was aware Mr. Labram had had no experience in gun-making, and he carried out the whole of his calculations and the whole of his work based upon the recollection of a lecture which presumably he had heard from the late Sir William Anderson, and by the assistance of illustrations in an engineering paper. Therefore the credit due to Mr. Labram and those who assisted him was so much the greater. There were just two points with regard to the troubles that arose on which perhaps he might be permitted to say a word or two. One was with reference to the fracture of the rings. It seemed very probable that the reason suggested for that fracture was correct, but another possible cause may have been unequal contraction and consequently unequal initial strains on the metal of the rings. With regard to the fracture of the stalk of the bolt, the oil annealing undoubtedly assisted in getting over the difficulty, but it struck him that had the sharp angle which was shown in Fig. 4, Plate 40, been largely curved, it was quite possible there would have been no fracture at all, even without the oil annealing. Still at the same time oil annealing was a common process for such work. He wished to express his appreciation of the clear way in which the description of the carrying out of the work was given in the Paper.

The CHAIRMAN thought the members would agree with him that Mr. Goffe deserved a hearty vote of thanks for his most interesting Paper; and on formally putting the motion it was carried unanimously.

RECENT LOCOMOTIVE PRACTICE IN FRANCE.

By M. EDOUARD SAUVAGE, *Member*,
Assistant Engineer-in-Chief, Rolling Stock and
Running Department, Western Railway of France.

(*Translated from the French.*)

Recent locomotives on the French railways are chiefly remarkable for their high power, rapid increase in the power of locomotives being not, however, peculiar to France.

Four-cylinder compound locomotives are frequently used: there are to-day in France more than 800 locomotives of this kind in service or under construction. The four cylinders drive either two, three, or four axles. With two driving axles the machines have large wheels, and are intended specially for working express trains, but they may also be employed advantageously for the heaviest passenger trains and even in certain cases for goods trains. The locomotives with three axles have also large wheels. They draw easily long goods trains or heavy passenger trains; they have been employed to work express trains, but exceptionally rather than regularly. This type of engine renders very great service, since it is suitable for almost all trains; it allows considerable increase in speed for goods trains, which becomes more and more necessary on the network of the principal French lines.

For heavy and slow trains, principally on steep inclines, four driving axles are used; but this type of machine is generally less in favour than the preceding: almost all engines with four driving axles have already become a little antiquated.

It is important to observe that much importance is attached to the preservation of the coupling of these axles together, instead of driving separately one axle or a group of axles by each pair of cylinders.*

The advance in the power of engines has brought about an increased weight upon each pair of wheels. A load of about 17 tons per axle is generally allowed to-day in France, although a a few years since 15 tons were seldom exceeded.

Amongst the details of construction one should notice first of all the dimensions of the fire-grates and of boilers. To obtain a sufficiently large diameter, especially with large wheels, the axis of the boiler has been raised much more than was done formerly; generally a height of 2·50 metres (8 feet $2\frac{7}{16}$ inches) above the rail-level is to-day the normal height, although formerly this dimension was nearer 2·15 metres (7 feet $0\frac{11}{16}$ inch). This necessitates the short chimneys characteristic of modern locomotives. It is scarcely necessary to add that engineers have never regretted this increased elevation of boilers; if there still exists a divergence of opinion in this matter, it is between those who think that there is no disturbance in the stability and those who think that there is a distinct advantage in this respect.

The effective pressure of steam in boilers has been carried to 14, 15, and even 16 kilogrammes per square centimetre (199, 213, and even 228 lbs. per square inch), the compound system making good use of these high pressures.

Referring to the frames of locomotives, the leading bogie has come into general use in France. All compound locomotives with four cylinders and two or three driving axles are thus furnished, with the exception of four constructed before 1889; many of the simple locomotives have also a bogie. Another instance of the favour with which bogies are regarded in France is seen in the addition of the bogie to old machines. It is also worthy of remark that elegance in the design of locomotives now receives more attention than formerly.

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* This remark does not apply to M. Mallet's articulated locomotives employed in France on the light railways of one-metre gauge, with which the present Paper does not deal.

The following information concerning the seven great railway lines of France, Nord, Ouest, État, Paris-Orléans, Midi, Paris-Lyon-Méditerranée, Est,* has been gathered with the kind co-operation of the chief mechanical engineers of these administrations, MM. du Bousquet, Clérault, Desdouits, Solacroup, Moffre, Baudry, and Salomon.

The present Paper does not deal with light railways of one metre, which would merit special consideration; it does not treat either of electric locomotives on trial or on order for the working of special lines. The author prefers to abstain from all comparison with English locomotives or those of other countries. Compound locomotives with four cylinders, other locomotives, and various details of construction will be examined successively.

I.—COMPOUND LOCOMOTIVES WITH FOUR CYLINDERS.

Table 1 (pages 398–399) gives a list of the compound locomotives with four cylinders in service or on order on 1st January 1900† for French railways (not including the Mallet locomotives for light railways of one metre as stated before). Amongst these locomotives of normal gauge, four (Nos. 2801–2804 État), constructed in America, are of the Vauclain system with superposed cylinders; twenty others (Nos. 4101 to 4120 Nord, constructed in 1889) have tandem cylinders with three piston-rods in each group and one valve for a group of two cylinders; these locomotives do not belong to the category of ordinary compound machines with intermediate receiver, but to that of the Woolf type with steam traversing direct from one cylinder to the other.

Putting on one side these two categories of locomotives, all others have four separate cylinders, each with its own valve and valve gear. The oldest of these locomotives is No. 701, Nord, Fig. 1,

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* These seven lines work the greater part of the network of French railways; there remains a system composed of light railways, generally with one-metre gauge.

† Since that date new orders have been given for locomotives of this kind. The Western Railway has decided on the construction of 40.

Plate 43, designed, like several of the following, by M. de Glehn, director of the Société alsacienne de constructions mécaniques. The two driving axles of this locomotive, No. 701, are not coupled. The high-pressure cylinders are inside and the low-pressure outside the frames.

In the following locomotives the positions of the cylinders have been changed, which gives the double advantage of placing the exhaust passage from the low-pressure cylinders beneath the smoke-box and fixing the smaller cylinders outside.

Locomotives with two driving axles developed from the first type have been constructed of larger and larger power; then followed the type with three driving axles, often with wheels large enough to permit their taking all except the most rapid trains. In order to still further increase the dimensions of the boilers of high-speed engines with two driving axles, the type called "Atlantic," with one carrying axle placed behind the two driving axles, Fig. 11, Plate 46, has been introduced. Two locomotives of this type are being constructed for the Northern Railway. One may consider the "Altantic" type as derived from the three-axles-coupled machine, where the trailing axle ceases to be a driver.

There is considerable uniformity among the two- and three-driving-axles locomotives employed on the different French railways; however the Paris-Lyon-Méditerranée has designed types of two, three, and also four-coupled axles which are peculiar to this line.

As already said, the coupling-rod has been preserved for two driving axles, to omit which would appear possible without inconvenience. It has been found in France that the disturbing forces due to the reciprocating movement of the pistons and the obliquity of the connecting-rods can be diminished by thus coupling the wheels; the machine runs more smoothly and wears the permanent way less. In addition to this, the coupled wheels are less prone to slip; in fact, with two independent axles, if one slips, the steam immediately acts with greater effort upon the other, making it slip in its turn.

Table 2 (pages 400–407) gives various dimensions of four-cylinder locomotives. In the most recent locomotives it will be seen that the grate area is about 2·5 square metres (27 square feet); for certain among them the heating surface approaches 200 square metres (2153 square feet). These heating surfaces are reckoned on the side of the plates and tubes in contact with the flame and hot gases. The surfaces indicated are not always comparable, for they are not always calculated in exactly the same manner; with the Serve-ribbed tubes very frequently used, the depth allowed in the calculations for the ribs is not always the same; besides, more or less is allowed for the omission of the ribs for expanding purposes at the two extremities of each tube.

The greater number of locomotives have a brick arch in the firebox. On certain engines of the Paris-Orléans and Midi railways the Tenbrinck heater exists.

The weights have been given, in Table 2, as they appear on the reports furnished to the author; but it is clear that these weights cannot be exact within 50 kilogrammes (1 cwt.); they must vary with the condition of the engine. The weights cannot be given for certain very recent and not yet completed locomotives.

Figs. 2 to 20, Plates 43 to 48, represent the particular types of four-cylinder locomotives. Those of the Paris-Orléans and State railways not given resemble the later types of the Southern line, with the exception of the American locomotives of the State railway.

The Walschaert valve-gear is employed generally in locomotives with four cylinders. This mechanism, having only one eccentric, is suitable for outside cylinders. It is also applied for inside cylinders; nevertheless the Gooch link has been employed for inside cylinders on the latest compound engines on the Paris-Lyon-Méditerranée. The Walschaert system gives good distribution of steam at the various points of cut-off.

The two lifting-shafts, one for the two high-pressure cylinders, the other for the low-pressure cylinders, are actuated by two reversing screws placed opposite each other, Fig. 21, Plate 49, or one a prolongation of the other, Fig. 22; the two can be reversed at will, either together or separately. The drivers are thus able to adjust suitably the distribution for all requirements, and have found from practice in a very short time the best working positions. Admission of steam to the large cylinders should always be at least from 40 to 50 per cent. of the stroke, and later for higher speeds.

On the Paris-Lyon-Méditerranée the reversing-shafts are, on the contrary, actuated at the same time, so that they always take the same fixed relative position.

In order to give the engines a sufficient starting effort, a special valve permits the direct admission of steam from the boiler into the receiver, where a safety valve limits the pressure. When the two connecting-rods situated on the same side of the engine are opposite one another, at 180° (the outside for the high-pressure cylinder, the inside for the low-pressure cylinder), the starting effort is not sufficient in certain positions of the engine, on account of the counter pressure upon the small piston of the steam admitted to the receiver; it has been found necessary to place between the two groups of cylinders special starting apparatus, Fig. 23, Plate 50. It consists of a large cock which can interrupt the passage from the small to the large cylinder, and which opens at the same time a direct escape for the small cylinders. A similar cock exists on each side of the engine. The opening of this cock transforms the locomotive to a simple 4-cylinder engine; in case of injury to one group of cylinders, it renders possible working with the other group only.

The system of the Est, Fig. 24, consists of a special box furnished with a flap-valve, which serves to separate the high-pressure and low-pressure cylinders, and a valve which opens a direct escape for the former. This apparatus receives the exhaust pipes from both high-pressure cylinders.

If the two cranks for the high and low pressure, instead of being opposite each other, are constructed with a suitable angle, a sufficient starting effort in all positions of the engine may be obtained without special apparatus other than the admission valve direct to the receiver. This was done on the first locomotives of the Paris-Lyon-Méditerranée; but this arrangement, which does not balance the weights of the parts so well, has been abandoned in recent designs.

For lubricating pistons and valves, the best apparatus consists of a kind of oil-pump, set in motion by the locomotive gear. This pump distributes oil to the four cylinders in precisely regulated quantities.

The preference given in France to four-cylinder compound locomotives appears justified. In the first place, when a very great power of the locomotive is required, the compound system permits the use of steam at a high pressure, 14 to 16 kilogrammes per square centimetre (199 to 228 lbs. per square inch), whilst preserving simple distribution and ordinary valves. The system gives economy of steam, or a larger power for the same expenditure, and when the engine has to be driven hard, this economy increases because the boiler is less forced.

In addition to this, compound locomotives with four cylinders have certain advantages over those which have only two or three; each cylinder producing only a smaller fraction of the total work, the engines are less strained, and remain in good order a longer time. It is well known to what rapid wear very powerful locomotives with two cylinders are exposed, because it is scarcely possible to give to the wearing parts sufficient bearing surface. In practice the cost of maintenance does not appear greater with four than with two cylinders from this reason.

The arrangement of four cylinders, whilst preserving the coupling of driving axles, leads to a balancing of the moving parts. The oscillations of the locomotives and the variation of the weights upon the rail are reduced. In one example, given by M. Baudry, Chief Engineer of the Paris-Lyon-Méditerranée, the additional weight upon each wheel due to speed was only from 1,100 to 1,200 kilogrammes ($1\frac{1}{16}$ to $1\frac{3}{16}$ ton) instead of 3,600 ($3\frac{1}{2}$ tons) for locomotives with two driving axles, and from 1,400 to 2,500 kilogrammes ($1\frac{3}{8}$ to $2\frac{1}{2}$ tons) in place of 6,600 kilogrammes ($6\frac{1}{2}$ tons) for locomotives with three driving axles, the wheels being 1 metre 50 (4 feet $11\frac{1}{16}$ inches) diameter.

If compound locomotives with four cylinders cost a little more than ordinary two-cylinder locomotives, this excess is largely compensated for by economy in fuel, because the cost of up-keep and repair does not appear to increase. The observations made upon locomotives 501 and 502 of the Ouest, which have been in service for some years, confirm these favourable opinions. These two machines have been compared with eight equivalent two-cylinder locomotives of the series 900. Care has been taken to put them to various duties, to employ exactly the same kind of fuel for all the engines, and to change the men often. The two compounds compared with the other engines have shown an economy in coal of 12 per cent. This economy would have been greater if the total amount used by engine 502 had not been always greater than that of engine 501, due no doubt to some small hidden defect. The cost of oil has not been greater for these compounds than for other locomotives.

With regard to wear, the tyres of locomotives 501 and 502 have run about 58,000 kilometres (or 36,000 miles), between each returning, whilst the other locomotives have run about 52,000 kilometres (32,000 miles): the removal of the wheels is the occasion of a slight general repair to the mechanism. The wear of the valves is considerably less with the compound locomotives, in spite of the high pressure in the boiler (14 kilogrammes per square centimetre in place of 12, 199 lbs. per square inch in place of 171 lbs.): the valves of the eight ordinary locomotives have been withdrawn after running about 69,000 kilometres (about 43,000 miles). The valves of the compounds have given the following services:—

Locomotive 501 .	H.P. valves, 215,000 and 332,000 kilometres (134,000 and 206,000 miles).
.	L.P. valves, 311,000 kilometres (193,000 miles) for both.
Locomotive 502 .	H.P. valves, 206,000 and 265,000 kilometres (128,000 and 165,000 miles).
.	L.P. valves, 362,000 kilometres for both (225,000 miles).

II.—Other Locomotives.

It may be interesting to mention in this section of the Paper the more important series of locomotives which have been in use for some time, but which are still doing good service, and the more recent non-compound types, as well as some special types.

1. *Simple Locomotives for High Speed.*—With the exception of very old locomotives, principally of the Crampton type, which only do secondary work, there are no longer in France any locomotives with independent axles. All express engines have two axles coupled; and, as stated above, locomotives with three-coupled axles and wheels of 1 metre 750 (5 feet 8$\frac{7}{8}$ inches) are now being employed in certain cases for express trains.*

The Nord employs bogie locomotives with inside cylinders and outside frames, Fig. 25, Plate 51, a type that has been in use for twenty years. The Ouest possesses sixty bogie locomotives, Fig. 26, of the type which was shown at the International Exhibition of 1889, the bogie having lateral play. Some État locomotives have two driving axles between two carrying axles, Nos. 2,602 to 2,620, Fig. 27, with the Bonnefond valve-gear. Each cylinder carries four valves, two for exhaust and two for admission. The latter are disposed for rapid closing by the action of a click.

It is interesting to note this application of the Corliss system to locomotives; the results appear satisfactory in practice, but up to the present it does not seem likely that the system will receive any considerable extension.

The État possesses also some two-axles-coupled locomotives, with the bogie having lateral displacement, and outside cylinders, constructed in 1896; these engines are furnished with cylindrical valves.

The Paris-Orléans has for a long time remained faithful to its old type with two coupled axles between two carrying axles, Fig. 28. Although in theory this type of locomotive presents certain inconveniences, it must be recognised that it has done long service with speeds often very high upon the Paris-Orléans system. These locomotives have outside cylinders, except three constructed in 1888, Nos. 101 to 103. The eight locomotives, Nos. 576 to 583, constructed in 1898, have the Durant and Lencauchez valve-gear with four independent valves for the cylinders. These valves oscillate round axes perpendicular to the cylinder axis, like those in Corliss engines, but there is no rapid closing of the admission valves. The distribution of the exhaust is regulated, in forward gear, by a point in the link more distant from the centre than the point which controls the admission distributors, in such a manner that the steam admission may be considerably reduced without unduly increasing the compression.

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* Fifteen years ago the Nord employed, for express trains between Calais and Boulogne, locomotives with three-coupled axles and wheels, 1·650 metre (5 ft. 4$\frac{15}{16}$ ins.) diameter. The inclines are 8 per 1000, or 1 in 125. On down grade the speed often reached 96 kilometres (59$\frac{5}{8}$ miles) per hour.

The principal dimensions of these locomotives, Nos. 576 to 583, are as follows:—

Grate area	2·11 sq. metres ($22\frac{5}{8}$ sq. ft.)
Heating surface	173·68 ,, (1869 sq. ft.).
Boiler pressure	15 kg. (213 lbs. per sq. in.)
Diameter of cylinders	420 mm. ($16\frac{1}{2}$ inches).
Stroke of pistons	650 mm. ($25\frac{9}{16}$ inches).
Diameter of driving wheels	1,800 mm. (5 ft. $10\frac{13}{16}$ ins.).
Weight in working order	47,900 kg. (47·14 tons).
Adhesive weight	32,000 kg. (31·49 tons).

The high steam-pressure, which is rarely used for simple expansion locomotives, is here noticeable. Similar locomotives in other groups have larger driving wheels.

The Est has applied the Durant and Lencauchez valve-gear upon two experimental locomotives. This mechanism appears suitable, but its use is, as yet, very limited. The old express locomotives of the Midi have two coupled axles, and a leading carrying axle. The cylinders are outside, and the driving crank pins are upon the hind axle.

The Paris-Lyon-Méditerranée has a large number of locomotives with two driving axles between two carrying axles, Fig. 29, Plate 52, similar to the Paris-Orléans arrangement. Formerly these engines hauled all the express trains. Today bogie engines are preferred for very high speeds. A certain number of these old engines have however been transformed to bogie engines, Fig. 30, and the employment of the Serve ribbed tubes has permitted a considerable shortening of the boiler barrel.

The old express locomotives of the Est have two coupled axles with one leading carrying axle. The driving crank-pins are upon the hind axle. To this type has succeeded a type, remarkable for its high power, constructed in 1890, Fig. 31; the arrangement of driving directly upon the trailing axle has been kept, but a leading bogie has been added. The boiler is of the double-bodied type by M. Flaman. The Est possesses forty locomotives of this kind (constructed between 1890 and 1895) of which the following are the principal dimensions:—

Grate area	2·418 sq. metres ($23\frac{1}{8}$ sq. feet).
Heating surface . . .	168·29 „ ($1811\frac{1}{2}$ sq. feet).
Boiler pressure. . . .	12 kg. (171 lbs. per sq. inch).
Diameter of cylinders . .	470 millimetres ($18\frac{1}{2}$ inches). (500 ($19\frac{11}{16}$ ins.) on the first engines).
Stroke of pistons . . .	660 mm. ($26\frac{1}{16}$ inches).
Diameter of driving wheels .	2·090 metres (6 ft. $10\frac{5}{16}$ ins.).
Weight in running order . .	56,766 kg. (55·87 tons).
Adhesive weight . . .	33,396 kg. (32·87 tons).

The construction of these engines marks a step in advance in the power of locomotives.

2. *Simple Locomotives with Three- and Four-coupled Axles.*—All French railways possess locomotives with three-coupled axles without a carrying axle, employed for ordinary passenger trains and goods trains. The cylinders are sometimes inside and sometimes outside. Several of these locomotives have a leading or a trailing carrying axle or a leading bogie. The Ouest constructed in 1896 four powerful locomotives of this description, with three-coupled axles and a bogie, Fig. 32, the cylinders and valve-gear being outside. These engines do good service, but the corresponding four-cylinder compounds are preferred.

Amongst the four-axles-coupled locomotives may be named those, Fig. 33, Plate 53, of which the Nord possesses a large number. The Woolf locomotive described above differs from these engines only in the arrangement of its cylinders.

3. *Tank Locomotives.*—Almost all tank locomotives of recent construction have three-coupled axles, but the Nord ordered, in

1891, 1893, and 1894, sixty two-axles-coupled bogie locomotives with outside cylinders, Fig. 34. These engines, of moderate power, are intended to draw light trains.

The État has also very small locomotives with two-coupled axles, and one carrying axle, Fig. 35, for secondary trains. In order to distribute suitably the weight upon the axles, a van (*fourgon*) has been added on the same frame.

The Ouest possesses a large number of tank engines with three axles, Fig. 36, very compact and convenient for local service. This type was built in 1883. Others were ordered in 1898; the modifications added to the engines during this period are of little importance. Similar engines are being built for the Ceinture (Girdle) Railway of Paris.

Recently the Ouest has ordered twenty-five more powerful tank locomotives with three-coupled axles and a bogie, Fig. 37, Plate 54, having outside cylinders and valve-gear. These locomotives are remarkable for their large capacity in storing water and fuel, often too limited in tank engines. This enables them to run considerable distances, and makes them suitable for a large number of passenger and goods trains. During some trials, one of these locomotives has attained a speed of 118 kilometres ($73\frac{1}{3}$ miles) per hour, although the diameter of the wheels is only 1·510 metre (4 feet $11\frac{7}{16}$ inches).

The principal dimensions are as follows:—

Grate area	1·80 sq. metre ($19\frac{3}{8}$ sq. ft.).
Heating surface . . .	131·60 ,, ($1416\frac{9}{16}$ sq. ft.).
Boiler pressure . . .	12 kg. per sq. cm. (171 lbs. per sq. in.)
Diameter of cylinders . .	460 mm. ($18\frac{1}{8}$ inches).
Stroke of pistons . . .	600 ,, ($23\frac{9}{16}$ inches).
Diameter of driving wheels .	1·510 metre (4 ft. $11\frac{7}{16}$ in.).
Capacity of water-tanks . .	7 cub. metres (1540 gals.).
Capacity of coal-bunkers . .	2·500 kg. (2·46 tons of coal).
Weight in running order . .	58,900 kg. (57·97 tons).
Adhesive weight . . .	43,900 kg. (43·21 tons).

The outside position of the mechanism is very handy; when it is inside, the side tanks render access difficult.

The Est has employed for some time powerful tank locomotives with three-coupled axles, having a trailing carrying axle, Fig. 38;

the cylinders are inside with outside frames, an arrangement seldom used. The principal dimensions are as follows :—

Grate surface	2·26 sq. metres ($24\frac{5}{16}$ sq. feet).
Heating surface	129·32 sq. metres (1392 sq. feet).
Boiler pressure	12 kg. per sq. cm. (171 lbs. per sq. inch).
Diameter of cylinders	460 mm. ($18\frac{1}{8}$ inches).
Stroke of piston	600 „ ($23\frac{9}{16}$ inches).
Diameter of driving wheels	1·560 metre (5 ft. $1\frac{7}{16}$ in.).
Capacity of water-tanks	5·220 cub. metres (1149 gals.).
Capacity of coal-bunkers	3,000 kg. (2·95 tons of coal).
Total weight in working order	60,027 kg. (59·08 tons).
Adhesive weight	45,236 kg. (44·52 tons).

It has been recently found advantageous to transform these locomotives by the addition of a leading bogie, Fig. 39, in order to permit high speeds without inconvenience. It has been decided to transform 50 machines out of 130.

The Paris-Orléans constructed some years ago powerful tank locomotives with three-coupled axles without a carrying axle, with exhaust condensing apparatus in the tanks, in order to work underground lines in Paris.

III.—DETAILS OF CONSTRUCTION.

New boilers are most often of the Belpaire type, the crown plates of the inside and outside shells being horizontal and stayed together. The smoke-box is long, in order to contain a large quantity of cinders. For some years ribbed tubes have been in general use. The tubes are generally 70 millimetres ($2\frac{3}{4}$ inches) external diameter; but the Paris-Lyon-Méditerranée use those of 65 millimetres ($2\frac{9}{16}$ inches) diameter. The trials made in the workshops of the Paris-Lyon-Méditerranée and of the Nord have shown that these tubes were just as suitable as ordinary tubes having the same internal surface in contact with the hot gases; the results obtained in service confirm these trials. The tube plates appear to last longer with these large tubes, because the distance between the holes is generally larger than with the ordinary tubes. On the other hand, one might have anticipated that the ribbed tubes would have an injurious action upon the plates, because they expand more than ordinary tubes, the ribs being more highly heated; but no inconvenience due to this cause appears to have been proved. For cleaning these tubes, a jet of steam is generally employed; but this jet does not always suffice, and it is necessary from time to time to clear out the deposits of coke from between the ribs.

Boilers are frequently constructed of mild steel plates; the fire-boxes are of copper; the trials of steel fire-boxes do not appear to have given any economy. For high pressures the plates are butt-jointed with covering strips (*couvre-joints*). The width of the two covering strips for longitudinal seams is not always the same, Fig. 41, Plate 55.

Direct-acting safety-valves (Adams, Lethuillier-Pinel, etc.) are more and more re-placing the old arrangement with a lever; these valves should be always kept in good order, as they are liable to give excessive escapes of steam.

In former French construction the barrel of the boiler rested on an intermediate support, which is now frequently omitted, the boiler being carried only by the smoke-box and the fire-box.

The injectors are often of the Sellers or Friedmann lifting type. They are not unfrequently mounted upon the fire-box back-plate with an internal delivery pipe.

For constructing parts such as cross ties and slide-bar brackets, cast steel is frequently employed. Cast steel is rarely used in France for wheels, which are usually made of stamped wrought iron after the Arbel type.

As has already been remarked, bogies are frequent. Whilst at the International Exhibition of 1889, only locomotives of the Nord and Ouest in the French section were furnished with bogies, engines are now no longer constructed in France without one, unless they are for suburban or shunting service.

The former bogie of the Nord had a fixed pivot, whilst that of the Ouest had a lateral movement; the latter arrangement is now always adopted, the lateral play being controlled by springs. The bogie of the Ouest with internal frames is still one of the simplest on French railways.

In order to facilitate the setting of the valves, and also for instruction of the men, an arrangement, already applied in Belgium by M. Guinotte on stationary engines, has been adopted upon some locomotives of the Ouest system; the piece which drives the valve spindle carries a templet of the longitudinal section of the valve, which moves over a fixed piece representing in section the cylinder ports, Fig. 42.

The tyres are often fixed simply by means of screws; frequently however they are fixed by the aid of a lip (*talon*) upon the tyre, and a steel ring locked in a groove in the tyre and riveted over the rim, Fig. 43.

Compound locomotives with two cylinders are little employed in France. In 1893 the Est constructed two engines of this kind with three coupled axles, Fig. 40, Plate 54. By mounting the cylinders between the outside frames a large space is afforded for fixing them; thus it has been possible to adopt diameters of 530 and 850 millimetres ($20\frac{7}{8}$ and $33\frac{7}{16}$ inches). Similar locomotives, but with two simple cylinders, have been constructed at the same time, and have been more successful in service.

The Midi is now rebuilding old locomotives as compounds with two cylinders.

The Nord has experimented with a three-cylinder compound engine, the middle cylinder being high pressure and the outside cylinders low pressure, all driving upon the same axle. This engine had three coupled axles, and a leading radial axle. Although this has not given bad results, it remains a unique example.

Cylindrical valves have been applied for a considerable time to a great number of locomotives on the État system, but up till now this mode of construction has spread but little in France. The Adams balanced valve has been used on a considerable number of locomotives on the Nord. The Est for some years past has made trials of this valve, and of the Richardson American valve. The latter railway is preparing an experiment on cylindrical valves. The general adoption of the compound system, which reduces the pressure on ordinary valves, explains the reason why these arrangements are somewhat neglected in France.

References.

The references to books and papers which follow, although far from complete, may be useful to readers who would wish for details of French locomotives:—

PULIN, A.—Results in service of the working of the Four-Cylinder Compound Locomotive, No. 701 of the Nord Railway. (Revue Générale des Chemins de fer, May and June 1887, pages 263 and 334.)

BAUDRY, CH.—Compound Four-Cylinder Express Locomotives of the Paris-Lyon-Méditerranée Railway. (Revue Générale des Chemins de fer, April 1893, page 178.)

———— On Compound Four-Cylinder Express Locomotives of the Paris-Lyon-Méditerranée Railway. See also the communication of M. Ch. Baudry in the discussion at the meeting of the Société des Ingénieurs Civils de France, 7 October 1898, page 47.

VALLANCIEN.—Eight Wheels Coupled, Four-Cylinder Compound Locomotives with one driving axle on the Paris-Lyon-Méditerranée. (Revue Générale des Chemins de fer, September, 1898, page 184.)

SALOMON, L.—Note on the Comparative Traction Trials between the Compound Engine of the Midi Railway, No. 1760, and the engines of the Est Railway, Series 800. (Revue Générale des Chemins de fer, September, 1897, page 134.)

———— Compound Express Locomotive of the Midi Railway: designs and description. (See "Engineering," 1899, II., page 591.)

PRIVAT.—Revue Générale des Chemins de fer, March 1896. (Extracts by Mr. Bryan Donkin, "Engineering," 1897, I., page 828.)

Compound Express Locomotive for the Northern of France Railway. ("Engineering," 1893 I., pages 70, 174, 233.)

Compound Express Locomotive for the Northern Railway of France. ("Engineering," 1898, I., pages 705 and 723.)

Wheels coupled, four-cylinder compound locomotives for the Eastern of France Railway. (Locomotive Magazine, 1899, page 137.)

Railway Exhibits at the Brussels Exhibition (Compound Locomotives). ("Engineering," 1897, II., page 706.)

MM. Schneider and Co.'s Works at Creusot, Construction Department (Locomotives). ("Engineering," 1898, II., page 284.)

Baudry, Ch.—Transformation to Bogie Locomotives of the Express Engines of the Paris-Lyon-Méditerranée Railway (type 1879). (Revue Générale des Chemins de fer, January, 1894, page 34.)

Locomotives of the Paris-Lyon-Méditerranée Railway. (Locomotive Magazine, 1899 and 1900.)

Express Locomotives for the Eastern Railway of France, with Flaman Boiler. ("Engineering," 1892, I., pages 391, 432, 507; Locomotive Magazine, 1899, page 119.)

Bonnefond's Locomotive Gear. ("Engineering," 1889, II., page 710.)

Locomotive for the State Railways of France, with Bonnefond Valve Gear. ("Engineering," 1894, I., page 742.)

Passenger Locomotive, Western Railway of France. ("Engineering," 1890, I., pages 674, 702.)

Tank Locomotive for the Western Railway of France. ("Engineering," 1889, II., page 599.)

Tank Locomotive for the Eastern Railway of France. ("Engineering," 1889, II., page 249.)

Pulin, A.—The New Four-Wheels-Coupled Tank Locomotive for light trains on the Northern Railway of France. (Revue Générale des Chemins de fer, January 1893, page 3.)

Northern Railway of France, Goods Compound (Three-Cylinder) Locomotive. ("Engineering," 1889, II., page 651.)

Adams, W.—High Pressures; Various Valve Gears. (Report to the Railway Congress in 1892, Vol. VI., XI–B.)

MORANDIÈRE, JULES.—Locomotives. (Proceedings of the Société des Ingénieurs Civils de France, July 1898, page 336.)

Locomotives at the Paris Exhibition in 1889. ("Engineering," 1889, II., page 96.)

Compound Locomotives. (Revue de Mécanique, 1897, pages 34, 228, 451, 732.)

TROISIER.—Note on Balanced Valves, and on their Application to some Locomotives of the Eastern Railway. (Revue de Mécanique, 1897, page 129.)

DEMOULIN, M.—Practical Treatise on the Locomotive. (Figs. 31 and 37 are taken from this treatise.)

BARBIER, F.—Experiments made in regular service on the express compound locomotive No. 2158 of the Northern Railway. (Revue Générale des Chemins de Fer, March and June 1898, pages 158 and 431, and July 1898, page 12.)

The Paper is illustrated by 13 Plates, Nos. 43–55.

APPENDIX.

ABBREVIATIONS FOR THE METRIC UNITS.

The utility of abbreviations for the names of the different metric units is obvious; too frequently such abbreviations are made at random and without any sensible rule, as for instance *kil*, which means kilomètres as well as kilogrammes. The International Committee of Weights and Measures,* at a meeting held on 2nd October 1879, arranged a list of such abbreviations in a simple and symmetrical manner, which are extensively used in the official publications of several countries, in a large number of periodicals and books, and in the proceedings of many societies; in fact, they are supposed to be everywhere understood without explanation, and none other should ever be used. These abbreviations are given on page 394.

As will be seen in this Table, for the names of the simple units, such as mètre, gramme, the initial letters *m*, *g*, are used; for the multiples, déca (10), hecto (100), kilo (1000), the initials *da*, *h*, *k*; and for the fractions déci (0·1), centi (0·01), milli (0·001), the letters *d*, *c*, *m*. In addition, to the micron (one-thousandth of a millimètre) corresponds the Greek letter μ; λ and γ express the microlitre (0·001 *ml* or one mm^3) and the microgramme (0·001 *mg*). Of course, these symbols must always be written without the addition of an *s*.

Some remarks may be made on the different parts of the Table. As regards Length, no abbreviations are provided for the *décamètre* (10 m.) and the *hectomètre* (100 m.), which, although convenient, are seldom used (according to the rules, these would be *dam* and *hm*). The *myriamètre* (10 *km*) is left out, for the same reason. The tenth and the hundredth of a millimètre have no symbols and even

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* This Committee was instituted in the year 1879, and included at the beginning sixteen countries: the United Kingdom joined it in 1884.

ABBREVIATIONS OF METRIC UNITS.

(As adopted by the International Committee of Weights and Measures.)

Length.		Surface.		Volume.		Capacity.		Weight.	
Kilomètre	km.	Square kilomètre	km^2.	Cubic mètre	m^3.	Hectolitre	hl.	Tonne	t.
Mètre	m.	Hectare	ha.	Stère	s.	Décalitre	dal.	Quintal métrique	q.
Décimètre	dm.	Are	a.	Cubic décimètre	dm^3.	Litre	l.	Kilogramme	kg.
Centimètre	cm.	Square mètre	m^2.	Cubic centimètre	cm^3.	Décilitre	dl.	Gramme	g.
Millimètre	mm.	Square décimètre	dm^2.	Cubic millimètre	mm^3.	Centilitre	cl.	Décigramme	dg.
Micron	μ.	Square centimètre	cm^2.			Millilitre	ml.	Centigramme	cg.
		Square millimètre	mm^2.			Microlitre	λ.	Milligramme	mg.
								Microgramme	γ.

no special names. This is to be regretted, as the tenth of millimètre is frequently mentioned in mechanical construction, and even the hundredth for very precise work, such as in the manufacture of guns. This deficiency might usefully be made up by the International Committee.

On the other hand, for greater units than the myriamètre, which would be useful in physics, geodesy, and astronomy, names are altogether missing. According to a well-known rule, the *mégamètre* might be adopted and would mean 1,000,000 *m* or 1,000 *km;* but this would not be sufficient in all cases. With too small or too large units, the numbers have too many figures, which convey no clear idea to our minds, and are not easily remembered.

In regard to Surface, the *are* is a square *décamètre*, or 100 m^2, and the *hectare* a square *hectomètre*, or 1000 m^2; to these is sometimes added the *centiare*, which is but a useless synonym of a square metre.

In respect to Volume, a *stère* is a cubic mètre of wood cut for fuel: it has only a limited use, and might be dropped out without serious inconvenience, at least in Great Britain.

In the measures for Capacity, a very bad feature indeed of the metric system is seen, as they have been established in defiance of the very principle of the system, no doubt with regard to old measures and customs. They are used for liquids and for solids, such as corn, peas, even potatoes, which easily fill a receptacle. The fundamental unit is the *litre*, or a cubic *decimètre;* there is no objection to the use of this short and useful name. But, multiplied by 10 and by 100, it gives the *décalitre* and *hectolitre*, which are false units, as the true measures of solidity, being the cubes of the measures of length, are each one thousand greater than the preceding; more specially from a didactic point of view, for children in the schools, for poorly educated people these units of capacity, which progress by ten, are destructive of any clear conception of the geometrical notions of length, square, and cube.

For teaching purposes, in the United Kingdom, it would be quite sufficient to say that the litre is a cubic decimètre, leaving aside these multiples and fractions of a litre.

The same criticism applies in some respect to the measures of weight, as the weights are derived from the volumes, one cubic decimètre of water being approximately a kilogramme. The only real units of weight are then the milligramme, the gramme, the kilogramme and the *tonne;* a *quintal* is only a certain number of kilogrammes (100 kg.) and not a real unit.

A more general remark applies to the name "units of weight": weight being a variable and not well defined property of matter, no unit of weight exists: these units are really units of mass, and should always be denominated as such.

TABLES 1 and 2.

TABLE 1 (*continued on opposite page*).

Four-cylinder Compound Locomotives,
in use or on order on 1st January 1900.
(Ordinary French gauge.)
LOCOMOTIVES WITH TWO DRIVING AXLES.

Fig.	Railway.	Nos. of the Series.	No.	Total.	Year ordered.	Remarks.
1	Nord (Northern)	701	1		1885	Driving axles not coupled; radial axle in front.
		2121–2123, 2137	17		1890 and 1892	
5		2138–2157	20		1894	
2		2158–2160, 2161–2180	23		1895 and 1897	
11		2641–2642	2	63	1898	Type "Atlantic."
3	Ouest (Western)	501–502	2		1893	
4 and 6		503–542	40	42	1897 and 1899	
	État (State)	2701–2706	6		1895	
		2801–2804	4	10	1899	American locomotives, Vauclain system.
	Paris–Orléans	1–20	20	20	1898	
7	Midi (Southern)	1701–1714	14		1893	
8		1751–1774	24		1895 and 1896	
		1775–1784	10	48	1897	
	P. L. M. (Paris, Lyons, and Mediterranean)	C 1–2	2		1887	Two driving axles between two carrying axles.
		C 3	1		1892	
		C 11–12	2		1891	
		C 21–60	40		1893	
9		C 61–150	90	135	1898	
10	Est (Eastern)	2401–2432	32	32	1898	
	Total No. of Locomotives with 2 driving axles			350		

(concluded from opposite page) TABLE 1.

Four-cylinder Compound Locomotives,

in use or on order on 1st January 1900.

(Ordinary French gauge.)

LOCOMOTIVES WITH THREE DRIVING AXLES.

Fig.	Railway.	Nos. of the Series.	No.	Total.	Year ordered.	Remarks.
13	Nord (Northern)	3121–3170	50	50	1897	
14 15	Ouest (Western)	2501–2525	25	25	1898	
	Paris-Orléans	1701–1725	25	25	1899	
17	Midi (Southern)	1301–1302	2		1895	
15		1303–1312	10		1897 and 1898	
		1401	1		1895	
16		1402–1415	14	27	1898	
	P. L. M. (Paris, Lyons, and Mediterranean)	3261–3300	40		1897	Locomotives with four driving-axles converted.
18		3401–3550	50	90	1898	
12	Est (Eastern)	3401–3460	60	60	1898	
	Total No. of Locomotives with 3 driving axles			277		

LOCOMOTIVES WITH FOUR DRIVING AXLES.

Fig.	Railway.	Nos. of the Series.	No.	Total.	Year ordered.	Remarks.
	Nord (Northern)	4101–4120	20		1889	Woolf's system of tandem cylinders.
20	P. L. M. (Paris, Lyons, and Mediterranean)	3201–3202	2		1887	
		4301–4302	2		1887	
		3211–3260, 3301–3362	112		1892 and 1893	
		4501–4540	40	176	1891 to 1895	Converted engines.
	Total No. of Four-cylinder Locomotives .			803		
	(This does not include Mallet double locomotives for the mètre-gauge light railways.)					

TABLE 2 (*continued to page* 407).

Principal dimensions of the Four-cylinder Compound Locomotives.

Fig.	Railway.	Nos. of the series.	Boilers.			Tubes.			Grat area.
			Internal diameter.	Height of axis above rail.	Pressure.	Length between plates.	External diameter.	No.	
			Mètres. *Ft. Ins.*	Mètres. *Ft. Ins.*	Kg. per Sq. Cm. *Lbs. per Sq. In.*	Mètres. *Ft. Ins.*	Milli-mètres. *Inches.*		Squa Mètre *Sq. Fe*
			LOCOMOTIVES WITH TWO DRIVING AXLES.						
1	Nord (Northern)	701	1·236 4 $0\frac{5}{8}$	2·150 7 $0\frac{11}{16}$	11 156	3·560 11 $8\frac{1}{8}$	45 $1\frac{3}{4}$	204	2·27 $24\frac{7}{16}$
		2121–2122	1·260 4 $1\frac{5}{8}$	2·250 7 $4\frac{9}{16}$	14 199	3·900 12 $9\frac{1}{2}$	70 $2\frac{3}{4}$	94	1·9 21
		2123–2137	1·260 4 $1\frac{5}{8}$	2·250 7 $4\frac{9}{16}$	14 199	3·900 12 $9\frac{1}{2}$	70 $2\frac{3}{4}$	94	1·9 21
5		2138–2167	1·256 4 $1\frac{7}{16}$	2·250 7 $4\frac{9}{16}$	15 213	3·900 12 $9\frac{1}{2}$	70 $2\frac{3}{4}$	94	1·9 21
		2158–2160	1·350 4 $5\frac{3}{16}$	2·450 8 $0\frac{7}{16}$	15 213	3·900 12 $9\frac{1}{2}$	70 $2\frac{3}{4}$	107	2·3 28
2		2161–2180	1·350 4 $5\frac{3}{16}$	2·450 8 $0\frac{7}{16}$	15 213	3·900 12 $9\frac{1}{2}$	70 $2\frac{3}{4}$	105	2·3 28
		2641–2642	1·456 4 $9\frac{5}{16}$	2·520 8 $3\frac{1}{4}$	16 228	4·200 13 $9\frac{3}{8}$	70 $2\frac{3}{4}$	126	2·7 $29\frac{1}{2}$
3	Ouest (Western)	501–502	1·296 4 $3\frac{1}{16}$	2·235 7 4	14 199	3·800 12 $5\frac{9}{16}$	70 $2\frac{3}{4}$	88	2·0 21
4 6		503–542	1·380 4 $6\frac{3}{8}$	2·485 8 $1\frac{13}{16}$	14 199	3·800 12 $5\frac{9}{16}$	70 $2\frac{3}{4}$	96	2·4 25
	État (State)	2701–2706	1·256 4 $1\frac{7}{16}$	2·250 7 $4\frac{9}{16}$	15 213	3·900 12 $9\frac{1}{2}$	70 $2\frac{3}{4}$	94	2·0 22
		2801–2804	1·588 5 $2\frac{1}{2}$	2·745 9 $0\frac{1}{16}$	15 213	3·670 12 $0\frac{7}{16}$	50 2	282	2·3 $25\frac{5}{8}$
	Paris—Orléans	1–20	1·378 4 $6\frac{1}{4}$	2·450 8 $0\frac{7}{16}$	15 213	3·900 12 $9\frac{1}{2}$	70 $2\frac{3}{4}$	111	2·4 $26\frac{1}{2}$

(*continued on next page*) TABLE 2.

Principal dimensions of the Four-cylinder Compound Locomotives.

Heating Surface.	Cylinders.				Driving Wheels.	Weight in working order.		Remarks.
	High-Pressure.		Low-Pressure.		Diameter.			
Square Mètres.	Diam.	Stroke.	Diam.	Stroke.		Total.	Adhesive.	
	Milli-mètres.	Milli-mètres.	Milli-mètres.	Milli-mètres.	Mètres.	Kg.	Kg.	
Sq. Feet.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Ft. Ins.*	*Tons.*	*Tons.*	
Locomotives with Two driving axles.								
103·03 1109	330 13	610 24	460 18⅛	610 24	2·100 6 10$\frac{11}{16}$	37,800 37·20	27,600 27·16	Low-pressure outside cylinders.
155·27 1671$\frac{7}{16}$	340 13⅜	640 25⅛	530 20⅞	640 25⅛	2·130 6 11⅞	47,800 47·04	30,500 30·02	
155·24 671	340 13⅜	640 25⅛	530 20⅞	640 25⅛	2·130 6 11⅞	48,620 47·85	30,520 30·04	
55·10 669½	340 13⅜	640 25⅛	530 20⅞	640 25⅛	2·130 6 11⅞	48,930 48·16	30,770 30·29	
75·75 891⅞	340 13⅜	640 25⅛	530 20⅞	640 25⅛	2·130 6 11⅞	50,460 49·66	31,010 30·52	
73·00 862¼	340 13⅜	640 25⅛	530 20⅞	640 25⅛	2·130 6 11⅞	52,400 51·57	32,400 31·89	
11·30 274½	340 13⅜	640 25⅛	560 22	640 25⅛	2·040 6 8$\frac{5}{16}$	64,000 62·99	33,000 32·48	Atlantic type.
23·20 326$\frac{3}{16}$	320 12$\frac{9}{16}$	640 25⅛	500 19$\frac{11}{16}$	640 25⅛	2·010 6 7⅛	46,050 45·32	28,650 28·20	
33·70 439$\frac{3}{16}$	340 13⅜	640 25⅛	530 20⅞	640 25⅛	2·010 6 7⅛	49,500 48·72	31,000 30·51	
57·66 97⅛	340 13⅜	640 25⅛	530 20⅞	640 25⅛	2·130 6 11⅞	50,000 49·21	32,135 31·63	
76·87 03⅞	330 13	660 26$\frac{1}{16}$	560 22	660 26$\frac{1}{16}$	2·140 7 0¼	54,880 54·02	32,060 31·56	Vauclain system.
75·61 90$\frac{5}{16}$	350 13¾	640 25⅛	550 21⅝	640 25⅛	2·090 6 10$\frac{5}{16}$	—	—	Tenbrinck heater in the fire-box.

TABLE 2 (*continued on next page*).

Principal dimensions of the Four-cylinder Compound Locomotives.

Fig.	Railway.	Nos. of the series.	Boilers.			Tubes.			Grate area.
			Internal diameter.	Height of axis above rail.	Pressure.	Length between plates.	External diameter.	No.	
			Mètres. *Ft. Ins.*	Mètres. *Ft. Ins.*	Kg. per Sq. Cm. *Lbs. per Sq. In.*	Mètres. *Ft. Ins.*	Milli-mètres. *Inches.*		Square Mètres. *Sq. Feet.*
		LOCOMOTIVES WITH TWO DRIVING AXLES (*continued*).							
7	Midi (Southern)	1701–1714	1·260 4 $1\frac{5}{8}$	2·250 7 $4\frac{9}{16}$	14 199	3·897 12 $9\frac{3}{8}$	70 $2\frac{3}{4}$	94	2·02 $21\frac{3}{4}$
8		1751–1774	1·380 4 $6\frac{3}{8}$	2·450 8 $0\frac{7}{16}$	14 199	3·900 12 $9\frac{1}{2}$	70 $2\frac{3}{4}$	111	2·46 $26\frac{1}{2}$
		1775–1784	1·376 4 $6\frac{3}{16}$	2·450 8 $0\frac{7}{16}$	15 213	3·900 12 $9\frac{1}{2}$	70 $2\frac{3}{4}$	111	2·49 $26\frac{13}{16}$
	P. L. M. (Paris, Lyons, and Mediterranean)	C 1	1·260 4 $1\frac{5}{8}$	2·250 7 $4\frac{9}{16}$	15 213	4·035 13 $2\frac{7}{8}$	50 $1\frac{15}{16}$	185	2·43 $26\frac{3}{16}$
		C 2	1·260 4 $1\frac{5}{8}$	2·250 7 $4\frac{9}{16}$	15 213	4·035 13 $2\frac{7}{8}$	45 $1\frac{3}{4}$	224	2·43 $26\frac{3}{16}$
		C 3	1·320 4 4	2·250 7 $4\frac{9}{16}$	15 213	3·000 9 $10\frac{1}{8}$	65 $2\frac{9}{16}$	133	2·43 $26\frac{3}{16}$
		C 11–12	1·320 4 4	2·250 7 $4\frac{9}{16}$	15 213	3·000 9 $10\frac{1}{8}$	65 $2\frac{9}{16}$	133	2·43 $26\frac{3}{16}$
		C 21–60	1·320 4 4	2·250 7 $4\frac{9}{16}$	15 213	3·000 9 $10\frac{1}{8}$	65 $2\frac{9}{16}$	133	2·38 $25\frac{5}{8}$
9		C 61–150	1·440 4 $8\frac{11}{16}$	2·470 8 $1\frac{1}{4}$	15 213	3·400 11 $1\frac{13}{16}$	65 $2\frac{9}{16}$	150	2·48 $26\frac{11}{16}$
10	Est (Eastern)	*2401–2432	1·463 4 $9\frac{9}{16}$	2·590 8 $5\frac{15}{16}$	16 228	3·400* 11 $1\frac{13}{16}$	70 $2\frac{3}{4}$	140	2·52 $27\frac{1}{8}$

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* The length of tubes for the compound locomotives, Nos. 2401–2432, apply only to th
(12 ft. $5\frac{9}{16}$ ins.), instead of 3·400 mètres, the heating surface being accordingly greater. The othe

(*continued on next page*) TABLE 2.

Principal dimensions of the Four-cylinder Compound Locomotives.

Heating Surface.	Cylinders.				Driving Wheels.	Weight in working order.		Remarks.
	High-Pressure.		Low-Pressure.		Diameter.			
Square Mètres.	Diam.	Stroke.	Diam.	Stroke.		Total.	Adhesive.	
	Milli-mètres.	Milli-mètres.	Milli-mètres.	Milli-mètres.	Mètres.	Kg.	Kg.	
Sq. Feet.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Ft. Ins.*	*Tons.*	*Tons.*	
LOCOMOTIVES WITH TWO DRIVING AXLES (*continued*).								
151·95 $1635\frac{5}{8}$	340 $13\frac{3}{8}$	640 $25\frac{1}{8}$	530 $20\frac{7}{8}$	640 $25\frac{1}{8}$	2·130 6 $11\frac{7}{8}$	50,800 50·00	31,800 31·30	
175·44 $1888\frac{1}{2}$	350 $13\frac{3}{4}$	640 $25\frac{1}{8}$	550 $21\frac{5}{8}$	640 $25\frac{1}{8}$	2·130 6 $11\frac{7}{8}$	54,000 53·15	32,800 32·28	
173·30 $1865\frac{7}{16}$	350 $13\frac{3}{4}$	640 $25\frac{1}{8}$	550 $21\frac{5}{8}$	640 $25\frac{1}{8}$	2·130 6 $11\frac{7}{8}$	—	—	
119·05 $1281\frac{1}{2}$	310 $12\frac{3}{16}$	620 $24\frac{3}{8}$	500 $19\frac{11}{16}$	620 $24\frac{3}{8}$	2·000 6 $6\frac{3}{4}$	53,500 52·66	29,600 29·13	A carrying axle at each end.
129·29 $1391\frac{3}{4}$	310 $12\frac{3}{16}$	620 $24\frac{3}{8}$	500 $19\frac{11}{16}$	620 $24\frac{3}{8}$	2·000 6 $6\frac{3}{4}$	53,500 52·66	29,600 29·13	Ditto.
148·09 $1594\frac{1}{16}$	340 $13\frac{3}{8}$	620 $24\frac{3}{8}$	540 $21\frac{1}{4}$	620 $24\frac{3}{8}$	2·000 6 $6\frac{3}{4}$	44,980 44·27	30,370 29·89	A carrying axle in front.
148·09 $1594\frac{1}{16}$	340 $13\frac{3}{8}$	620 $24\frac{3}{8}$	540 $21\frac{1}{4}$	620 $24\frac{3}{8}$	2·000 6 $6\frac{3}{4}$	47,910 47·16	30,150 29·67	
148·07 $1593\frac{7}{8}$	340 $13\frac{3}{8}$	620 $24\frac{3}{8}$	540 $21\frac{1}{4}$	620 $24\frac{3}{8}$	2·000 6 $6\frac{3}{4}$	50,600 49·80	31,880 31·30	
189·51 $2039\frac{15}{16}$	340 $13\frac{3}{8}$	620 $24\frac{3}{8}$	540 $21\frac{1}{4}$	620 $24\frac{3}{8}$	2·000 6 $6\frac{3}{4}$	—	—	
184·70 $1988\frac{1}{8}$	350 $13\frac{3}{4}$	640 $25\frac{1}{8}$	550 $21\frac{5}{8}$	660 $26\frac{1}{16}$	2·070 6 $9\frac{1}{2}$	59,218 58·29	33,778 33·24	Pressure reduced to 15 kg. per sq. c.metre, or 213 lbs. per sq. inch.

Nos. 2401–2408; in the remainder, Nos. 2409–2432, the length of the tubes is 3·800 mètres dimensions remain the same.

TABLE 2 (*continued on next page*).

Principal dimensions of the Four-cylinder Compound Locomotives.

Fig.	Railway.	Nos. of the series.	Boilers.			Tubes.			Grate area.
			Internal diameter.	Height of axis above rail.	Pressure.	Length between plates.	External diameter.	No.	
			Mètres. *Ft. Ins.*	Mètres. *Ft. Ins.*	Kg. per Sq. Cm. *Lbs. per Sq. In.*	Mètres. *Ft. Ins.*	Milli-mètres. *Inches.*		Square Mètres *Sq. Feet*
		Locomotives with Three driving axles.							
13	Nord (Northern)	3121–3170	1·380 4 $6\frac{3}{8}$	2·420 7 $11\frac{1}{4}$	15 213	4·100 13 $5\frac{7}{16}$	70 $2\frac{3}{4}$	107	2·34 $25\frac{3}{16}$
14 15	Ouest (Western)	2501–2525	1·446 4 $8\frac{15}{16}$	2·410 7 $10\frac{7}{8}$	14 199	4·300 14 $1\frac{5}{16}$	70 & 45 $2\frac{3}{4}$ & $1\frac{3}{4}$	117	2·45 $26\frac{3}{8}$
	Paris—Orléans	1701–1725	1·380 4 $6\frac{3}{8}$	2·420 7 $11\frac{1}{4}$	15 213	4·100 13 $5\frac{7}{16}$	70 $2\frac{3}{4}$	107	2·38 $25\frac{5}{8}$
	Midi (Southern)	1301–1302	1·380 4 $6\frac{3}{8}$	2·420 7 $11\frac{1}{4}$	14 199	4·100 13 $5\frac{7}{16}$	70 $2\frac{3}{4}$	111	2·46 $26\frac{1}{2}$
17		1303–1312	1·376 4 $6\frac{3}{16}$	2·420 7 $11\frac{1}{4}$	15 213	4·100 13 $5\frac{7}{16}$	70 $2\frac{3}{4}$	111	2·49 $26\frac{13}{16}$
		1401	1·380 4 $6\frac{3}{8}$	2·345 7 $8\frac{3}{8}$	14 199	4·100 13 $5\frac{7}{16}$	70 $2\frac{3}{4}$	111	2·46 $26\frac{1}{2}$
16		1402–1415	1·376 4 $6\frac{3}{16}$	2·345 7 $8\frac{3}{8}$	15 213	4·100 13 $5\frac{7}{16}$	70 $2\frac{3}{4}$	111	2·49 $26\frac{13}{16}$
	P. L. M. (Paris, Lyons, and Mediterranean)	3261–3300	1·400 4 $7\frac{1}{16}$	2·260 7 $4\frac{15}{16}$	15 213	3·000 9 $10\frac{1}{8}$	65 $2\frac{9}{16}$	139	2·45 $26\frac{3}{8}$
18		3401–3550	1·440 4 $8\frac{11}{16}$	2·435 7 $11\frac{13}{16}$	15 213	3·400 11 $1\frac{13}{16}$	65 $2\frac{9}{16}$	150	2·48 $26\frac{11}{16}$
12	Est (Eastern)	3425–3450	1·466 4 $9\frac{3}{4}$	2·450 8 $0\frac{7}{16}$	16 228	4·100 13 $5\frac{7}{16}$	70 $2\frac{3}{4}$	130	2·51 27

(continued on next page) TABLE 2.

Principal dimensions of the Four-cylinder Compound Locomotives.

Heating Surface.	Cylinders.				Driving Wheels.	Weight in working order.		Remarks.
	High-Pressure.		Low-Pressure.		Diameter.			
Square Mètres.	Diam.	Stroke.	Diam.	Stroke.		Total.	Adhesive.	
	Millimètres.	Millimètres.	Millimètres.	Millimètres.	Mètres.	Kg.	Kg.	
Sq. Feet.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Ft. Ins.*	*Tons.*	*Tons.*	
LOCOMOTIVES WITH THREE DRIVING AXLES.								
180·70	350	640	550	640	1·750	58,570	42,470	113 ribbed tubes of 70 mm., or $2\frac{3}{4}$ inches, and 4 smooth tubes of 45 mm., or $1\frac{3}{4}$ inch diam.
$1945\frac{1}{8}$	$13\frac{3}{4}$	$25\frac{1}{8}$	$21\frac{5}{8}$	$25\frac{1}{8}$	5 $8\frac{7}{8}$	57·65	41·80	
194·00	350	640	550	640	1·720	58,400	41,500	
$2088\frac{1}{4}$	$13\frac{3}{4}$	$25\frac{1}{8}$	$21\frac{5}{8}$	$25\frac{1}{8}$	5 $7\frac{11}{16}$	57·48	40·84	
187·97	350	640	550	640	1·750	—	—	
$2023\frac{3}{8}$	$13\frac{3}{4}$	$25\frac{1}{8}$	$21\frac{5}{8}$	$25\frac{1}{8}$	5 $8\frac{7}{8}$			
181·51	350	640	550	640	1·750	57,500	41,700	
$1953\frac{11}{16}$	$13\frac{3}{4}$	$25\frac{1}{8}$	$21\frac{5}{8}$	$25\frac{1}{8}$	5 $8\frac{7}{8}$	56·59	41·04	
181·74	350	640	550	640	1·750	60,100	44,300	
$1956\frac{5}{16}$	$13\frac{3}{4}$	$25\frac{1}{8}$	$21\frac{5}{8}$	$25\frac{1}{8}$	5 $8\frac{7}{8}$	59·15	43·60	
181·51	350	640	550	640	1·600	56,500	40,700	
$1953\frac{13}{16}$	$13\frac{3}{4}$	$25\frac{1}{8}$	$21\frac{5}{8}$	$25\frac{1}{8}$	5 $2\frac{15}{16}$	55·61	40·06	
181·74	350	640	550	640	1·600	59,900	44,100	
$1956\frac{5}{16}$	$13\frac{3}{4}$	$25\frac{1}{8}$	$21\frac{5}{8}$	$25\frac{1}{8}$	5 $2\frac{15}{16}$	58·96	43·41	
154·74	360	650	590	650	1·500	58,110	44,010	Converted engines.
$1665\frac{5}{8}$	$14\frac{3}{16}$	$25\frac{9}{16}$	$23\frac{1}{4}$	$25\frac{9}{16}$	4 $11\frac{1}{16}$	57·19	43·32	
189·51	340	650	540	650	1·650	—	—	
$2039\frac{15}{16}$	$13\frac{3}{8}$	$25\frac{9}{16}$	$21\frac{1}{4}$	$25\frac{9}{16}$	5 $4\frac{15}{16}$			
205·31	350	640	550	640	1·750	65,368	47,096	Pressure reduced to 15 kg. per sq. c.metre, or 213 lbs. per sq. inch.
2210	$13\frac{3}{4}$	$25\frac{1}{8}$	$21\frac{5}{8}$	$25\frac{1}{8}$	5 $8\frac{7}{8}$	64·34	46·35	

TABLE 2 (*concluded from page* 400).

Principal dimensions of the Four-cylinder Compound Locomotives.

Fig.	Railway.	Nos. of the series.	Boilers.			Tubes.			Grate area.
			Internal diameter.	Height of axis above rail.	Pressure.	Length between plates.	External diameter.	No.	
			Mètres.	Mètres.	Kg. per Sq. Cm.	Mètres.	Milli-mètres.		Square Mètres.
			Ft. Ins.	*Ft. Ins.*	*Lbs. per Sq. In.*	*Ft. Ins.*	*Inches.*		*Sq. Feet.*
		Locomotives with Four driving axles.							
	Nord (Northern)	4101–4120	1·478 4 $10\frac{3}{16}$	2·050 6 $8\frac{11}{16}$	10 142	4·099 13 $5\frac{3}{8}$	50 $1\frac{15}{16}$	199	2·08 $22\frac{3}{8}$
	P. L. M. (Paris, Lyons, and Mediterranean)	3201–3202	1·400 4 $7\frac{1}{16}$	2·260 7 $4\frac{15}{16}$	15 213	4·350 14 $3\frac{1}{4}$	40 & 45 $1\frac{9}{16}$ & $1\frac{3}{4}$	307 & 247	2·45 $26\frac{3}{8}$
		4301–4302	1·500 4 $11\frac{1}{16}$	2·260 7 $4\frac{15}{16}$	15 213	4·150 13 $7\frac{7}{16}$	50 & 55 $1\frac{15}{16}$ & $2\frac{3}{16}$	247 & 210	2·21 $23\frac{3}{4}$
20		3211, 3260 and 3301–3362	1·400 4 $7\frac{1}{16}$	2·260 7 $4\frac{15}{16}$	15 213	3·000 9 $10\frac{1}{8}$	65 $2\frac{9}{16}$	139	2·45 $26\frac{3}{8}$
		4501–4510	1·500 4 $11\frac{1}{16}$	2·260 7 $4\frac{15}{16}$	15 213	2·995 9 $9\frac{7}{8}$	65 $2\frac{9}{16}$	184	2·10 $22\frac{5}{8}$
		4511–4520	1·500 4 $11\frac{1}{16}$	2·260 7 $4\frac{15}{16}$	15 213	3·007 9 $10\frac{3}{8}$	65 $2\frac{9}{16}$	184	2 14 23
19		4521–4530	1·500 4 $11\frac{1}{16}$	2·260 7 $4\frac{15}{16}$	15 213	3·007 9 $10\frac{3}{8}$	65 $2\frac{9}{16}$	184	2·10 $22\frac{5}{8}$

(concluded from page 401) TABLE 2.

Principal dimensions of the Four-cylinder Compound Locomotives.

Heating Surface.	Cylinders.				Driving Wheels.	Weight in working order.		Remarks.
	High-Pressure.		Low-Pressure.		Diameter.			
Square Mètres.	Diam.	Stroke.	Diam.	Stroke.		Total.	Adhesive.	
	Milli-mètres.	Milli-mètres.	Milli-mètres.	Milli-mètres.	Mètres.	Kg.	Kg.	
Sq. Feet.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Ft. Ins.*	*Tons.*	*Tons.*	
LOCOMOTIVES WITH FOUR DRIVING AXLES.								
124·30	380	650	660	650	1·300	52,800	52,800	Tandem cylinders.
1338	15	$25\frac{9}{16}$	$26\frac{1}{16}$	$25\frac{9}{16}$	4 $3\frac{3}{16}$	51·97	51·97	
164·74 & 154·89	340	650	540	650	1·500	56,900	56,900	307 tubes of 40 mm., or $1\frac{9}{16}$ ins., on one engine, and 247 of 45 mm., or $1\frac{3}{4}$ ins., on the other.
$1773\frac{5}{16}$ & $1667\frac{1}{4}$	$13\frac{3}{8}$	$25\frac{9}{16}$	$21\frac{1}{4}$	$25\frac{9}{16}$	4 $11\frac{1}{16}$	56·00	56·00	
159·55 & 151·12	360	650	540	650	1·260	57,100	57,100	247 tubes of 50 mm., or $1\frac{15}{16}$ ins., on one engine, and 210 of 55 mm., or $2\frac{1}{8}$ ins., on the other.
$1777\frac{7}{16}$ & $1626\frac{11}{16}$	$14\frac{3}{16}$	$25\frac{9}{16}$	$21\frac{1}{4}$	$25\frac{9}{16}$	4 $1\frac{5}{8}$	56·20	56·20	
154·74	360	650	590	650	1·500	53,700	53,700	
$1665\frac{5}{8}$	$14\frac{3}{16}$	$25\frac{9}{16}$	$23\frac{1}{4}$	$25\frac{9}{16}$	4 $11\frac{1}{16}$	52·86	52·86	
202·06	340	650	520	650	1·300	51,500	51,500	Converted locomotives.
2175	$13\frac{3}{8}$	$25\frac{9}{16}$	$20\frac{7}{16}$	$25\frac{9}{16}$	4 $3\frac{3}{16}$	50·69	50·69	
202·10	340	650	520	650	1·300	50,900	50,900	
$2175\frac{7}{16}$	$13\frac{3}{8}$	$25\frac{9}{16}$	$20\frac{7}{16}$	$25\frac{9}{16}$	4 $3\frac{3}{16}$	50·10	50·10	
202·88	340	650	520	650	1·300	51,660	51,660	
$2183\frac{7}{8}$	$13\frac{3}{8}$	$25\frac{9}{16}$	$20\frac{7}{16}$	$25\frac{9}{16}$	4 $3\frac{3}{16}$	50·85	50·85	

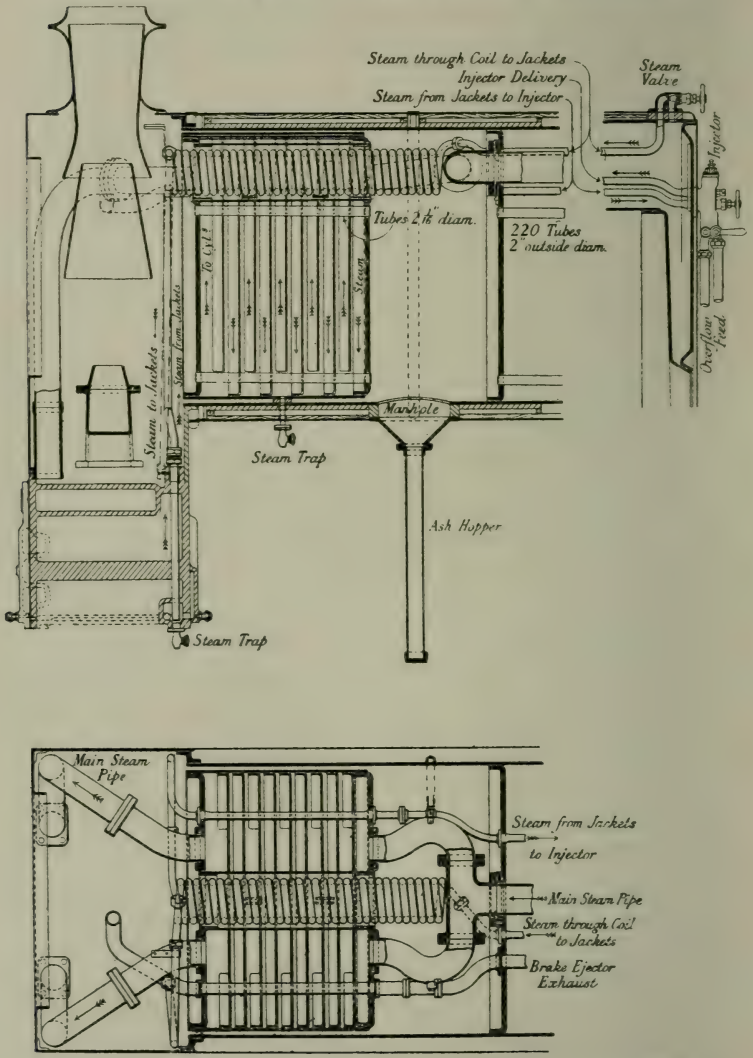
Discussion.

Mr. JOHN A. F. ASPINALL, Vice-President, considered that locomotive engineers in this country were again indebted to his friend M. Sauvage for giving them the benefit of his experience on the Continent. It was not the first time that M. Sauvage had given, in the most lucid way, his figures and his facts. With regard to the use of compound locomotives on the French railways, there was one thing which he would like to elicit from the author, and that was, whether they were using those engines continuously for stopping trains as well as for through trains, and if so what had been the result in fuel consumption. Hitherto in this country there had been an idea that the compound locomotive was much more suited for fast traffic, where heavy trains were pulled over long distances without stopping, than it was for stopping trains, and that, where a compound locomotive was used for stopping trains, much of the economy that might be obtained by compounding was run away with by having to admit high-pressure steam to the low-pressure cylinders for starting purposes. If M. Sauvage could say definitely what had been done on the French railways in the way of saving fuel, he thought it would be a most interesting fact. It was the old question of economy in the coal, and after all that was a most important thing. It was a question of what could be saved by compounding. The question was becoming a very serious one, particularly in the North of England. There had recently been an increase in the price of coal of about 60 per cent., and that made it necessary to look round and see if anything could be done by compounding. But taking what might be considered a high price for coal, and leaving out the question of the 60 per cent. increase which had now come, speaking about coal at a fairly high price for the North of England, about 10*s.* a ton, and assuming that a locomotive burnt 1,000 tons of coal in the year, and without taking the rosy figure of 12 per cent. which M. Sauvage talked about as a saving, calling it 10 per cent., it was a very easy calculation to see that if 10 per cent. were saved on 1,000 tons of coal costing 10*s.*

per ton, £50 a year would be got out of it. But £50 a year would very soon be run away with in the maintenance of the extra parts used for the compounding engines, and therefore he pressed the question of economy in fuel.

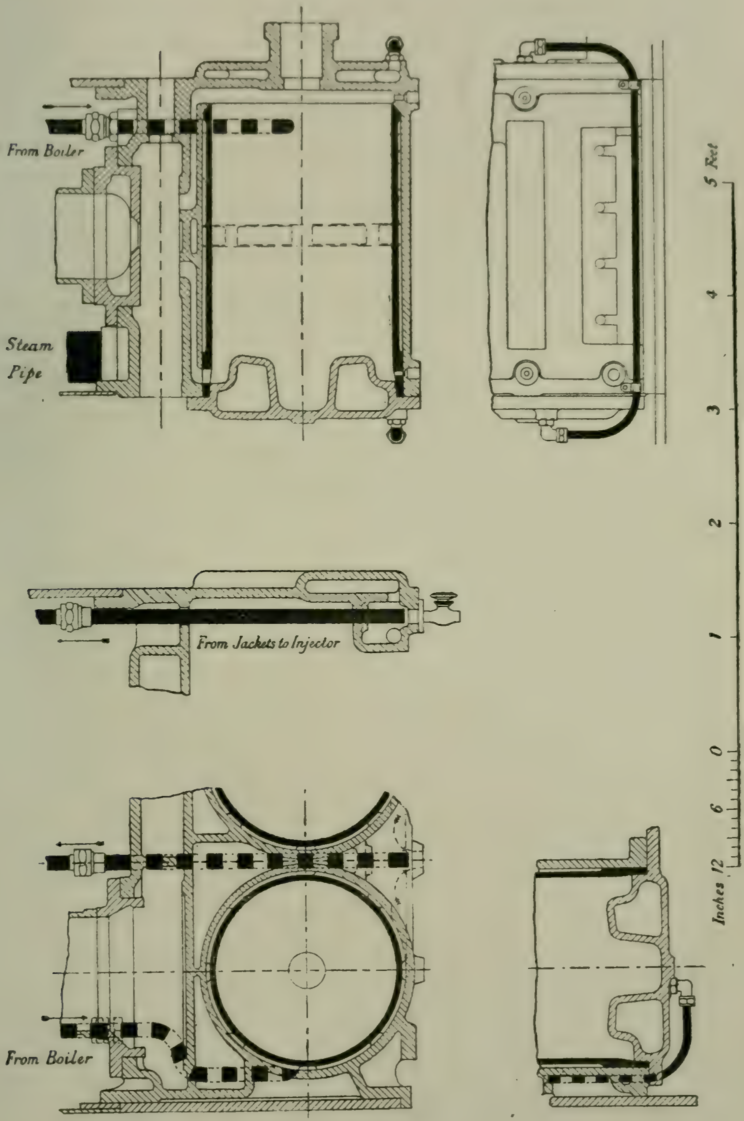
Turning to another matter which M. Sauvage had mentioned—engines of the Atlantic type, Plate 46—there had been built on the Lancashire and Yorkshire Railway recently twenty large engines of that type, and with a view to reducing the coal bill without adding to the number of working parts, all those engines had had steam-jacketed cylinders, 19 inches by 26 inches, Fig. 45, page 411; and in order to ensure that the driver should continuously make use of the arrangement, the steam which worked the injector was made to sweep through the jacket on its way to the injector so that the cylinder took up a certain amount of heat, the cylinders were kept hot, and the condensed steam was not lost. The officials of the railway thought they were getting some advantage from that. Special arrangements were of course made for taking away any water of condensation, such as accumulated when the engine was standing at the station, but otherwise during the whole journey the injector was kept going, and any little water that was made in the cylinder jacket was swept into the injector and back into the boiler. That was one thing. Another thing was that of that lot of engines nineteen were built all alike, while the twentieth had its boiler barrel shortened internally. Externally the appearance was exactly the same as the others, but internally the boiler barrel was considerably shortened, and that gave, as it were, a kind of extended smoke-box inwards, and the space in that smoke-box was made use of to insert a large superheater, Fig. 44, page 410, which was cylindrical in shape, with two tube-plates at either end. Through those tube-plates were a number of tubes equal in number to those going through the boiler barrel, slightly larger in diameter, to enable the boiler tubes proper to be withdrawn for repairs, and a space was left between the superheater and the tube-plate of the boiler proper, with suitable arrangements for getting in between, so that the boiler tubes proper could be thoroughly cleaned out, as well as the tubes that went through the superheater. The superheater had, in addition to the tubes running horizontally through it, about four or five diaphragms, (Mr. John A. F. Aspinall).

FIG. 44.—*Arrangement of Steam Superheaters for Main Steam and Jackets.*
10-Wheeled Bogie Passenger Engine, L. and Y. Ry.
4 wheels coupled, Cylinders 19 *inches diam.* 26 *inches stroke.*



Scale $\frac{1}{32}$

FIG. 45.—*Arrangement of Steam-Jacketed Cylinders. L. and Y. Ry.*



(Mr. John A. F. Aspinall).

running vertically, through which the tubes passed, so that the steam which came from the regulator was made to pass through the superheater down to the bottom of the superheater, come up again past the diaphragm, and so on, picking up the heat from the exterior surface of the tubes on its way to the cylinders. It certainly had resulted in enabling very dry steam to be got to the cylinders, but the experiment had not been conducted sufficiently long to enable anything to be said as to whether it was really a great commercial success. After all, what was desired to know was what influence that was going to have upon the coal heap, and that was why he asked his friend, M. Sauvage, to say what influence his compounding had had upon his coal consumption.

Mr. Henry A. Ivatt, Member of Council, was sure the Members were all very much indebted to M. Sauvage for bringing his very interesting Paper before them, and adding such valuable information to the Proceedings of the Institution, and he thought they were further indebted to him for reading the Paper in English. Speaking for himself he should be very sorry to stand up before a French audience and try to say anything about locomotives in broken French. The thing that struck him about the Paper was the great increase in the power of locomotives which had taken place in France during the last ten years. The measure of the power of a locomotive was the boiler. Mr. Sturrock, who left the position, which he himself now occupied on the Great Northern Railway, over thirty years ago (and who he was glad to say came to see him at Doncaster and talk locomotives now and then), said that the measure of the power of a locomotive was "its capacity to boil water." It would be seen from the Paper that a great many of the boilers of the French locomotives were quite up to 2,000 feet of heating surface, and a great many of the fire-boxes had over 20 feet of grate area, and in many cases the pressure was over 200 lbs. It was no use having large cylinders, and figuring the power of the engine from the cylinders, unless one had a boiler that would keep the cylinders properly supplied. A large purse was not of much advantage unless the bank account was capable of keeping it well filled. One of the difficulties which locomotive engineers had to deal with was trying to pull very big trains at very high speeds. When a locomotive engineer made an engine that was capable of pulling a church, he was at once asked to hitch on the schools as well! What was required for running heavy fast expresses was to start with an engine of the dray-horse type, capable of exerting great tractive force, and quickly getting up the speed to about 50 miles an hour; then to take that engine off, and put on another of the quick trotter or high-flyer type. Of course that was impossible in practice, but it seemed to him that the four-cylinder compound, with plenty of adhesive weight, was likely to be a solution of the difficulty. A four-cylinder compound, with a boiler big enough to allow all four cylinders to work by high pressure, not for a short distance only, but for many miles when necessary, fitted with a simple arrangement which would allow the engine to be worked compound at will, might perhaps assist in the direction he had tried to indicate. The author was quite right when he said that there were two sets of opinions on locomotive matters; sometimes the drawing-office size of a blast-pipe was not the same as the steam-shed size. In 1895 he compounded one of the express engines on the Great Southern and Western Railway of Ireland, and that engine had been running ever since. The experience obtained with that engine went to show that the cost of repairs and renewals was not greater than with other non-compound engines. That bore out what the author said with reference to the cost of upkeep of compound engines, and with regard to fuel consumption he was informed by Mr. Coey, present locomotive engineer of the Great Southern and Western Railway, that the engine was no better and no worse than other simple engines doing the same work. In conclusion he congratulated M. Sauvage on his interesting Paper.

Professor L. P. BRECKENRIDGE said he was certainly very glad to step on the platform of the Institution of Mechanical Engineers. Within the last two or three years he had been interested in perfecting certain devices at the University of Illinois which, co-operating with certain of the trunk lines running through the

(Professor L. P. Breckenridge).

town, had been used to make some experiments with locomotives. The University engineers had been able to construct a test-car on what was called the "Big Four" railroad, and this had been in operation for two years, during which numerous experiments had been made with it. Before he left America, the Illinois Central Railway had completed a second railway test-car for the University of Illinois, in order that the University might co-operate with the railway in making certain tests. He had attended at a great many Railway Clubs in America, and was glad of the opportunity of seeing M. Sauvage and other gentlemen who knew about those things. He found in the Proceedings of the Institution, which were in his library from the initial volume of 1847, a great many things interesting to Americans about the construction and operation of locomotives. He had stepped off the steamer about twenty-four hours previously, and had gone directly to the locomotive. It looked really peculiar to him. It did not seem at first sight as if the engineers in this country knew how to build locomotives, although he expected they did. He found, as he grew older, he appeared to know less, and was inclined to think that by the time he had lived to be thirty or forty years older he might be able to see some things which he did not understand now as to the reason of the peculiar construction of locomotives which were seen in Great Britain and on the Continent. The question of the "Serve" tube had interested him a great deal. He had tested them in his laboratory, to determine their transmission of heat, as compared with that of plain tubes of different thicknesses and compositions. He was trying to carry out a series of experiments to determine the fall of heat through tubes of different sizes when coated with different thicknesses of scale. The question of feed-water for locomotives was a very serious one in America, and after six months' service, or sometimes after two months' service, scale on the tubes appeared to him to be occasionally one-eighth of an inch thick. Compared with compounding, this question of making steam, even with a large boiler, was of greater importance to them. He thoroughly agreed with the remarks that had been made as to there being two sides to the locomotive question. He had found that what one official in the executive department thought right was not always in accord with the experience of the operator. The question of the best size of the exhaust, which was mentioned by Mr. Ivatt, had opened a question which had for some time been under investigation in the laboratory at the University of Illinois, and the members might be interested to know that recently one of his students had invented an exhaust-tip, which appeared new to him, but might be old with people in this country. Instead of the usual circular tip, it consisted of eight radial trapezoidal ports, aggregating 20 per cent. greater area than the usual circular area. Indicator diagrams and observations on the smoke-box vacuum had been made with those engines, and the eight blades of steam had been arranged with the idea of entraining between the blades the gases in the smoke-box. He thought that the action of the blast was largely due to two things—the jet action and the entraining action. In the new tip the entraining action was the most important part. It had been found to reduce the back-pressure against the piston at least 50 per cent. in a large number of the engines to which it had been applied, and at the same time the vacuum in the smoke-box had been actually increased. That had reduced the coal consumption in twenty-five locomotives over 7 per cent. It was now in use on over fifty engines on the Illinois Central. It had been put in within the last year, and he spoke of it more because it originated from the experimental work of one of the graduates in the department of Mechanical Engineering. The serious back-pressure of 12 lbs. to 18 lbs. per square inch had thus been considerably reduced. They had been thus far applied to simple engines, about 18 inches to 26 inches, and in all of these the fire seemed to burn much better. In America the cheapest coal that could be bought was frequently used on the locomotive. He thought that with the device described very little trouble had been experienced. There seemed to be a more uniform continuous draught through the fire than there was with the other intermittent and jumpy sort of draught.

Mr. BRYAN DONKIN, Member of Council, said there was only one question he wished to ask on the interesting Paper of M. Sauvage--

(Mr. Bryan Donkin).

for which the Institution ought to be very grateful—and that was with reference to the general economy of the compound over the ordinary locomotive engine. If he had understood it rightly, it was about 12 per cent. He did not understand whether in each case the cylinders were jacketed or otherwise, and also whether the pressure of the steam was about the same in the two sets of trials. To make a fair comparison, the pressures of steam in the boilers should be similar.

Mr. BOWMAN MALCOLM did not know that he could add very much to what had been said before, beyond stating that he was a "compound man." For the past ten years he had worked compound engines on the two-cylinder principle, and the economy found had been something over 12 per cent., but it was right to mention that the pressure was 15 lbs. greater in the compound than in the simple engines. As Mr. Ivatt had said (page 413) with regard to the engine he compounded on the Great Southern and Western Railway, there was no additional cost in maintenance, there were no additional working parts, and in every way the engines had proved most satisfactory. He had no experience of four-cylinder compounds, but he was inclined to agree with the statements made in the excellent Paper which had just been read, as he thought in future it was necessary to have larger engines. The weight of trains was continually increasing, and the accommodation given to travellers was very much in excess of what it was in former years, and he fancied the limit had been reached of the biggest engine it was possible to make with two cylinders. His own compound engines were all two-cylinder engines, and each was fitted with an apparatus by which it always started as a simple engine, high-pressure steam passing to both cylinders at starting, and in cases of emergency the driver had power to let the steam out of the reservoir on the high-pressure side of the intercepting valve, so that high-pressure steam continued to go to the low-pressure cylinder, and the full boiler-pressure was effective on the high-pressure cylinder—an arrangement which gave the engine a tremendously high starting power. It was only valuable however at very slow speeds, and was simply an emergency valve, but it was found of very great advantage, especially in the case of goods engines.

He had used the Walschaert valve-gear for all his compound engines (both inside and outside cylinder), and found it in every way satisfactory; not only did this valve motion give a good distribution of steam at the various points of cut-off, but it was very easily and economically maintained; and in the case of inside cylinder engines, as only one eccentric is required for each cylinder, it gave ample room for long journals—the journals of the coupled axles of his engine being 11 inches long. With regard to the working of the engines, he wished to state that they were used for all kinds of traffic, express passenger, ordinary passenger, suburban, and goods, and owing to the peculiar circumstances of the line all classes of engines had a considerable amount of shunting to do—both passenger and goods—and in his experience they performed all classes of work, even the shunting, as smartly as simple engines, but many traffic officials were of a different opinion. This he attributed to the fact that the engines were less "fussy," only beating twice per revolution instead of four times; in fact he had satisfied himself by repeated experiments that compound engines started as quickly, either light, lightly loaded, or heavily loaded, as simple engines of the same type and power. He also found that the emission of sparks—doubtless owing to the softness of the blast—was much less than in the case of simple engines, and doubtless from the same cause compound engines ran a much longer distance than simple engines without the fire being cleaned; and the accumulation of ashes in the smoke-box was much less. He wished to add his word of thanks to M. Sauvage for the very interesting Paper, which he thought would be a great addition to the information on locomotives already contained in the Proceedings of the Institution.

Mr. JOHN RIEKIE said it gave him great pleasure to be allowed to say a few words about the question of increase in cylinder capacity in locomotives, which he believed was the main cause of increase in the power. Taking, for instance, the largest of the four cylinders of the French engines that were now running, the increase in

(Mr. John Riekie.)

cylinder capacity was about 60 per cent. larger than could be had with a two-cylinder simple engine having 20-inch cylinders. That increase in power was no doubt looked upon as a substantial gain, especially when it was considered that it was effected without any increase in steam consumption, the same weight of steam being used over larger piston surface. If it was acknowledged that greater power could be obtained by an increase in cylinder capacity, then he failed to understand why locomotive engineers were adopting the very type of engine that prohibited them from increasing the cylinder capacity to its maximum limit. It was well known that the greater the area of the low-pressure cylinder the greater would be the power when a given volume of steam was used to a very low pressure. It was also known that the more work got out of the steam, the greater would be the economy, and to get that it was necessary to use as large a low-pressure cylinder as practicable, with as low a pressure of steam as possible. The adoption of the four-crank locomotives limited the diameter of the low-pressure cylinder to 24 inches, owing to the restrictions in gauge and leading dimensions. He thought the members would agree with him when he said that they could not expect very great power from such a low-pressure cylinder as one 24 inches in diameter, especially if steam of 15 to 20 lbs. was to be used in the cylinder. If on the other hand steam of a very high pressure was used, then the engine might be a very powerful one, but in his opinion would not be an economical one. He would try and show how it was practicable to get not only a greater cylinder power but at the same time economy in steam consumption. When designing an engine he adopted a three-crank one, but a very important feature was that the three cranks had to be placed at angles of 120° apart, for by so doing he could make use of very large high-pressure cylinders. Again he had had to adopt a new ratio of cylinder area to suit his system. In that way he was able to use up a given weight of steam for a larger piston surface than any system hitherto used. For instance, when applying the system to a locomotive he could use two high-pressure cylinders outside the frames having a diameter of 24 inches, and one inside the frames with a diameter of 38 inches. Those cylinders gave a piston surface of 1,931 square inches, or 90 per cent. more than could be had with the four-cylinder engine under discussion. It had been said that the English locomotive had reached its limits of power, but he thought that such was not the case, and that there were means at hand by which it could be almost doubled. For the present light loads now hauled by engines, and often two engines, he would recommend an engine having two 20-inch high-pressure cylinders, and one 31½-inch low-pressure one, or 40 per cent. more than the four-cylinder engine which had been mentioned, leaving a fair margin for a future day to haul the heavy palatial Pullman cars that were being sent over from America. Two engines on that system were at work on the Indian State Railways, and were giving very satisfactory results.* He would be pleased to show any member a model of the pistons and cranks, which would show very clearly how he was able to get more work with a given weight of steam than could be obtained by any other system, which was applicable to all and every type of engine from a motor car to the largest and most powerful engine.

Professor WILLIAM H. WARREN, of Sydney University, said he was very sorry he had been asked to speak, as he had not been interested in such matters for years. He might just describe an experiment that was made some years ago in New South Wales. About five years ago he was made a member of the Royal Commission to enquire into the merits of certain engines from America which were made by the Baldwin Locomotive Co., of Philadelphia. Trials of those engines were made on the grades of one in forty and one in thirty, and indicator diagrams were taken. The water, coal, speed, and all the necessary data were measured as far as possible to get at the actual performances of the engine. About the same time a number of engines were made by Messrs. Beyer Peacock and Co., of Manchester, of exactly the same power—they were of the same size and about the same weight, the Beyer Peacock engine weighing 87½ tons, and the Baldwin engine 93 tons. They each had three

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* "The Engineer," 20 July 1900, page 55.

(Professor William H. Warren.)

axles coupled, and a double bogie in front. They were designed for the same traffic, and were as nearly as possible the same. The performances were, however, somewhat different. The Beyer Peacock engine was capable of drawing a heavier load at a higher speed on the inclines. Both engines were carefully tested, and the curious thing was that the Beyer Peacock engine burnt very much less coal. He mentioned this matter because the Paper under discussion dealt with compound engines, and Messrs. Beyer Peacock also designed an engine exactly the same as the before-mentioned 10-wheel engine, and made it a compound engine. There was not space to put on a larger low-pressure cylinder, and consequently they had two low-pressure cylinders and one high-pressure. The boiler pressure was the same, and the engines were the same in every particular, and were tested under the same conditions. The result was that the compound engine indicated about 150 horse-power less than the simple engine. It certainly did not burn quite so much coal, but it would not give out the power, and so they had been converted back to the original type of engine. With the conditions under which the engines were used, the compound did not appear to have any very great advantages. Probably if instead of the two cylinders which were necessary on account of the space, one low-pressure cylinder had been used, there would have been better results, but it was not possible to do it under the circumstances, nor could it be done in this country on account of the existing station-platforms and other restrictions. Those were the facts, and he would not express an opinion upon them, because there were so many members present more competent to do so than he was.

Mr. WILLIAM SCHÖNHEYDER said Mr. Riekie (page 419) had mentioned that he had been able to obtain certain results, better than anybody else could, by having two high-pressure cylinders and one low-pressure cylinder. He did not remember quite the sizes which were mentioned, but it appeared to him that he added together the capacity of the three cylinders, and then because that capacity was large, thought he was therefore able to get very high results. The capacity of a compound engine was practically measured by the capacity of the low-pressure cylinder, and if that cylinder was small it was impossible to get any high advantage from compounding.

Professor **WILFRID J. LINEHAM** said there was only one point to which he wished to call attention, and as the real question under discussion was economy, he did not think he was departing from the subject of the Paper. The members all knew that the most wonderful economy in land engines had been obtained when drop valves had been used. The slide-valve was known to lose a quantity of the engine's energy by steam leakage, but drop valves could always be kept tight. The old objection to drop valves was that they were not fit for rapid vibration, on account of their weight and the consequent hammering action. This had been proved no objection at all in the recent motor car experience. Such valves vibrated at an enormous rate, about 1,000 times per minute, and why therefore were drop valves not permissible on locomotives? He did not believe that he should at present have locomotive engineers with him; he believed they had an objection to drop valves, but he seriously thought such valves should be tried, and he expected to find the before-mentioned economy by their use. He should further like to draw the attention of the members to the intimate connection that appeared to exist, according to Professor Breckenridge (page 413), between the engineering schools and the railway lines in America.

Mr. **JAMES E. DARBISHIRE** said there was a little information he might be able to add to what had been said about compound engines. Professor Warren (page 419) had mentioned an experiment made on the New South Wales Railways with an engine that was hardly a fair example, because it was built under restricted conditions as regards space, and therefore the builders, Messrs. Beyer Peacock and Co., with whom he was connected, had to put two low-pressure cylinders instead of one, and as Professor Warren said, it handicapped the engines to some extent. Another reason was that the pressure in the compound engine was the same as it was in the simple, and therefore

(Mr. James E. Darbishire.)

the engines were not quite under equal conditions. A compound engine was naturally a means of using a higher pressure than could be used in a simple engine. He might mention that some other engines were built by the same firm for a railway abroad; the first was simple, but as the superintendent, who was not in favour of compounding at all, was desired by his directors to try compound engines, a second was built at the same time, exactly the same as the simple, excepting that it had a higher pressure, and was compounded on the Worsdell and von Borries' system. The compound engine gave very considerably better results in economy of fuel than the simple engine. Therefore the superintendent, who was an Englishman, began to think about it, and concluded that it was only on account of the higher pressure; he then ordered a simple engine of the same type with the higher pressure—the same pressure as the compound. That engine gave very much better results than its sisters with the lower pressure, as was to be expected, but it was not quite equal to the compound engine. The superintendent at last came to adopt the compound entirely, and all his engines on that line had been since compounded. The case there was one to which Mr. Aspinall had alluded—of pulling a big train without stopping. It was only a metre-gauge line, but the trains were made up to as much as the engines would take; the inclines were heavy, and the curves sharp, and it was hard collar work for perhaps 15 or 20 miles at a time, then a short run down, and then more collar work. It was all hill climbing with a big train. There it seemed that the compound engine obtained an advantage. The same thing had been found in the Argentine Republic on the broad gauge, where they had enormous trains with very level lines; the engines were steadily "pegging away" for miles without stopping. But when the compound engine had been introduced, as it had been frequently, for what might be called local service, it did not seem to answer. It might work perfectly well, but the economy was not there. He was speaking entirely of the two-cylinder system of compounding, because he had never had any experience of the four cylinders. The latter system might, and very likely would, answer quite as well as the two-cylinder system, and it seemed to him to have advantages on 4 feet 8½ inch railways such as had to be dealt with in this country and in France, because it was not possible with comfort to get two large cylinders in between the frames. His friend Mr. Malcolm had gained very satisfactory results with inside cylinder compound engines, but he had a 5 feet 3 inch gauge, which was much larger than the gauge in this country. It made a great difference if it was possible to get plenty of bearing surface for the axles by having a broad gauge. That could not be had in this country, and therefore it seemed to him it was necessary to use three or four cylinders if compounding was to be done. He desired to ask M. Sauvage whether on any of the French railways a type of tank engine had been adopted, which was common in this country. He had never seen one in France, but then he had not travelled much there. He referred to the type of suburban engine with four wheels in front coupled, and a four-wheel hind bogie. It was very common in this country, and, so far as he had been informed, a very successful type.

Mr. J. D. Twinberrow wished to say a few words upon one point in M. Sauvage's excellent Paper which he considered constituted the chief merit of the four-cylinder compounds as developed with such success in France, namely, the self-balancing of the reciprocating parts. He did not think there could be two opinions amongst railway engineers as to the desirability of completely balancing the reciprocating parts for high-speed work. He believed that the designs originated by M. de Glehn provided for the balance of the primary forces only, leaving the couples unbalanced. At the time when Mr. Yarrow was achieving a notable success by balancing high-speed marine engines by applying reciprocating bob-weights, he, the speaker, ventured to throw out the suggestion that the same end might more readily be attained by adjusting the masses of the reciprocating parts, and by selecting suitable angles between the cranks, in order that there should be self-balancing of multi-cylinder engines. He noticed M. Sauvage referred to the fact that these engines would start better without an intercepting valve, if the

(Mr. J. D. Twinberrow.)

angle between the adjacent high and low pressure cranks diverged somewhat from 180°, but when that divergence had been tried the balance had been interfered with. In view of the conspicuous success which Messrs. Yarrow and Co. had obtained in working out the self-balancing of engines, and because a compound four-cylinder locomotive would start better, and have a more even torque with that arrangement of angles between the cranks, he should like to ask M. Sauvage whether it had ever been considered advisable in France to apply that method of balancing (now known as the Yarrow, Schlick, and Tweedie system) to the locomotive, in order that not only the primary forces but also the couples and secondary forces due to angularity might be completely balanced. He also wished to point out that it was very undesirable to couple, as had sometimes been done, four cylinders on to one driving axle. That increased the stresses on the crank axle, and also those on the coupling rods, and it did not in any way improve the balance. The correct principle was undoubtedly that which had been adopted throughout the four-cylinder engines built in France, of coupling the high-pressure cylinders to one axle, and the low-pressure to another. It was interesting to observe that the consumption of lubricating oil for the four-cylinder engines had not gone up as compared with the simple engines. He did not think the same could be said for any other class of compound engine. If he could venture to prophesy he would be inclined to think that the next development would be the enclosing of the working parts, and the supply of oil under pressure to every joint. The system which had been so successful in stationary work, if applied to the locomotive, would lead to an increase in mechanical efficiency, dispensing largely with wear and tear, and, more important than all, would enable a better daily mileage to be obtained from engines, because it would eliminate a very considerable portion of the time occupied by the engine men in attending to trimmings, oiling up, and wiping up the four or five drops of oil that were wasted for every one that did useful work. With respect to coal consumption, he did not think any compound engine had surpassed the relative results that had been achieved by the compound goods engine of Mr. T. W. Worsdell. Compared with modern standards they were only a low powered class, but they could be relied upon, when not hampered by frequent stoppages or much shunting, to show a saving of about 16 per cent. as compared with a similar class of engine with simple cylinders. They had special starting valves, which enabled them to make one stroke as ordinary engines. They were not handy in shunting, and were slow in starting, but if they were fitted with a simple form of intercepting valve between the cylinders, of the type used on the Northern of France Railway, as illustrated in the Paper, it would enable them to get away and to shunt as ordinary simple engines, and in all probability the type would then be much more widely adopted. He thought M. Sauvage would agree that in connection with nearly all classes of traffic it should be said that "*Le démarrage doit être rapide !*" and unless it was so, it was impossible to get economy with a compound engine where the stops were at all frequent and where shunting had to be done.

Mr. ALFRED SAXON said the one point that had struck him most about the discussion was that while locomotive engineers were looking about them for larger cylinders and larger boilers, they seemed to be overlooking one fact entirely, namely, that this was an electrical age. Although an electric locomotive had proved more or less of a failure, still he thought locomotive engineers ought to be considering the application of electricity to train traction in this country, especially as it was such a small country. America was so large a country that it could hardly tackle such a question as the electric traction of trains, but it was possible to do so in this country, and he was rather surprised that locomotive engineers were looking to every other source but the source which they would have to deal with before long.

M. SAUVAGE, in reply, said, although many interesting remarks had been made on the Paper, he would confine himself to the more direct questions, as time was much limited. With regard to the chief point, coal consumption, he had been asked whether it must be expected to find in practice the 10 to 15 per cent. economy, which had been proved in nearly all experiments. That was a difficult

(M. Sauvage.)

question to answer with precision, because the working conditions differed so much from the experimental conditions. Every time a compound locomotive had been compared with a simple one under similar conditions, economy of steam had been found to be 10 to 15 per cent.; nearly every published experiment agreed in that respect. In actual practice was it possible to guarantee that, by using a compound engine, 10 or 12 per cent. of coal would be saved? This had been found in actual practice,* but of course it depended on the working conditions. As a rule the compound engines replaced ordinary locomotives which were less powerful. With heavy trains, some economy might result merely from the use of a more powerful locomotive with a larger boiler, an economy which was quite independent of the system used—simple or compound. On the other hand, if large compound engines were used to take light trains, the consumption might be unduly increased. In fact, the coal consumption depended in some respects upon the use which was made of the locomotive; it was naturally expected that the locomotive would be used as intelligently as possible. Still, in some cases the working conditions would not always allow the best utilisation of locomotives. For these reasons it might be sometimes difficult to prove that in practice an economy of 10 to 12 per cent. resulted from the use of compound locomotives, but everything tended to show that it existed. Taking for instance the Western Railway of France, the engineers of that line thought that, when it was suggested to build the four-cylinder compound engines, they could guarantee that the cost, taking everything into account, would not be greater than with less powerful simple engines; they even believed the cost would be a little less. With these four-cylinder compounds the initial cost was a little higher; the cost for repairs was the same, and the cost for fuel less, thus compensating largely for the higher initial expenditure.

Another question was, were the compound locomotives fit for trains which frequently stopped? Compound locomotives had not yet been used in France for suburban trains (Mallet engines excepted), but in some cases they took ordinary trains, which made frequent stoppages, and in those cases they were found to work well. As the number of these locomotives did not at present amount to 10 per cent. of the whole stock in France, and as they were the best and most powerful, they were generally used for the more important passenger and goods trains; but there was no objection in principle to making use of them for ordinary trains. The starting mechanism, which transformed the compound into a locomotive with four single cylinders, was in fact not much used. In many cases the locomotive could start without working that device at all. When the special starting apparatus was worked, it was in most cases only for one or two revolutions, so that the extra steam consumption could not be very large on that account, and nevertheless a good speed might be attained in a short time, which was of capital importance, as remarked by Mr. Twinberrow. Of course there was always the loss of heat while the locomotive was standing, or running down a grade without steam on, and that slightly lowered the percentage of economy due to compounding. Mr. Donkin (page 416) asked if the steam pressure in the boiler was the same in compound and ordinary locomotives. The steam pressure has been generally a little less in the ordinary locomotive, namely, 12 kilogrammes per square centimetre for ordinary locomotives of the latest construction, instead of 14 or 15 with the compound. Although from this higher pressure may result a saving not due to compounding proper, in the ordinary locomotive with single cylinders it was rather difficult to make use of such a high pressure, at least with the ordinary mechanism for distributing steam. It must be regarded as an advantage of the compound system that it permitted the use of a very high pressure, which could not be used in the old engine with the ordinary valve motion. The cylinders were not jacketed; and it was a great pleasure to have heard that such an able engineer as Mr. Aspinall had succeeded in applying jackets, which certainly were very good additions. It was only from difficulties in construction that as yet they had not been more used.

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* See page 431.

(M. Sauvage.)

With regard to the best size of cylinders, certain average dimensions were generally adopted for a given class of locomotives, according to the size of the boiler; but these dimensions could not be calculated to an extreme nicety, and the cylinders might be a little smaller or a little wider than the average. From his own practice, it seemed advisable to have cylinders a little too small rather than too large; pressure was more easily maintained in the boiler, and, under ordinary circumstances, the engine worked better. No definite rules could be laid down in that respect.

A question had been put as to the balancing of the engine, which was a most important question. The balancing of the four-cylinder compound was not complete. Only the reciprocating parts were balanced, and not completely, as the parts moving in opposite directions were in different planes; but with the four-cylinder compound system the balancing was better than on the ordinary locomotive.

With regard to the use of tank engines with coupled wheels in front and a bogie (page 423), that type was not employed in France. The nearest approach to this type was seen in some locomotives, used on the Northern Railway with three-coupled axles under the boiler and a bogie in the rear. The last question was with regard to setting the two cranks for the high pressure and for the low pressure. Engines had been made by one railway company to dispense with a starting apparatus, by setting the corresponding high and low pressure cranks at a different angle than 180 degrees; but now every one agreed that the balancing was of greater importance than the saving of a small starting apparatus. This special setting of the cranks had been abandoned in the latest designs. In conclusion, the author thanked the members for their kind appreciation of his Paper.

The CHAIRMAN, in moving a hearty vote of thanks, which was accorded to M. Sauvage for his interesting Paper, hoped that he would reply in writing to any other point which had been raised in the discussion.

Communications.

Mr. **Dugald Drummond** wrote that he had read M. Sauvage's Paper with some interest, but regretted to find no information to enable an opinion to be formed in comparing the two systems of locomotives dealt with in his Paper. It would therefore be interesting if the author would kindly give full particulars as in Tables 1 and 2 (pages 398–407) of the two-cylinder engines of modern type which were being replaced by four-cylinder engines, supplementing it with the train load, speed, and a complete set of indicator diagrams of both classes of engines working express trains, the coal consumption per horse-power per hour and the coal consumption per ton of train per mile.

He noticed that the economy in coal consumption of 12 per cent. of the Ouest 501 series over the 900 might be almost entirely due to the difference in boiler pressure, which was 28 lbs. per square inch higher in the four-cylinder than in the other. In order to make comparisons, and to form a correct judgment as to the system now adopted in France being comparable with the practice adopted in this country, with a view to economy, it was absolutely necessary that the engines should be working under similar conditions.*

Mr. **David Joy** wrote that, when he excused himself at the Meeting from entering into the discussion on M. Sauvage's Paper, he was so deeply interested in listening to the information being given on the question by the many able and practical men who spoke on the subject, that he quite forgot his own obligations to his fellow-members, and that he had something to say on the compounding of locomotives, a subject in which he had been practically interested from the first, as well as in the allied and earlier question of compounding at sea. He regretted to note the confirmed report of a saving of only 12 per cent., which admittedly only covered extra expenses, while in marine practice the application of compounding and triple compounding had proved to be the life of the steam-engine at sea.

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* See also pages 416, 420, and 422.

(Mr. David Joy.)

He had had the good fortune, after a lengthened and practical connection with railway working, to be placed in a somewhat similar connection with marine work, and thus to have been in touch with some of the early applications of the compound system at sea. From the first these gave much more satisfactory results than 12 per cent. saving in fuel, as well as more promising prospects, which had been in every way realized. Referring to the early applications and the subsequent treatment of compounding at sea, and on the rails, it would have to be admitted that the system had had a far better chance on the former than on the latter. To quote one of the earliest cases at sea, namely the application of this system to the steamers of the Pacific Steam Ship Co., by Messrs. Elders:—the engines were entirely renewed on designs to meet the new requirements for steam; the pressure and the piston area were doubled, thus affording a large margin for the employment of a degree of expansion. The result was an increased speed on half the consumption of fuel, which had been followed up, and greatly advanced upon; while in the earlier locomotives, in which the ordinary boilers, or those slightly strengthened, were used, the pressures were but little raised above that usually employed, the piston-area being increased only about 50 per cent., and having but a slight margin for increased expansion and little room for saving fuel. The practice had not been enlarged upon to any considerable extent since, and nothing to allow of the high degree of expansion that might be advantageously employed at the high speeds run, and the consequent high piston-speed attained.

The writer thought that the solid advances made at sea in every direction gave certain promise of at least a large advance in the same direction on the rails, but it would be by the employment of much higher degrees of expansion, which meant a higher pressure and a larger piston-area. He had held for a long time that there was a far better result to be obtained on the rails than the standard 12 per cent., by following more nearly in the course adopted at sea.

M. SAUVAGE wrote that on the Western Railways, as was customary in France, a certain allowance of coal was made, calculated after the average work of each engine, and premiums were paid to the crews for economy on these allowances. These consisted of two parts, a fixed weight of 4·5 to 5 kilogrammes (9·92 to 11 lbs.)* for each kilomètre of train, and a certain weight for each ton carried at a distance of 1 kilomètre. This second part varied from 38 to 50 grammes (1·25 to 1·60 ounces) for each ton-kilomètre. The figures differed for express, ordinary, and goods trains, and were the same for all engines from one running shed, according to the local conditions of service; but for the two-coupled compounds a reduction of 5 per cent. on these last figures had been made, and of 10 per cent. for the three-coupled compounds. Notwithstanding the coal premiums paid, economy of fuel with these compounds was rather high, and a further reduction might take place.

The actual consumption in 1899 was, for the ordinary express locomotives (series 900) and for the two-coupled compounds (Nos. 503–522), as follows:—

	Compound Locomotives.	Ordinary Locomotives.
Total No. of kilomètres run	533,452	978,599
Average weight of trains, in tons (1,000 kg.) .	185	127
Kilogrammes of coal per kilomètre	9·25	9·23
„ „ per 100 tons × 1 kilomètre†	5	7·22

M. Baudry, Engineer-in-chief (locomotive superintendent) of the Paris-Lyon-Méditerranée Railway, had kindly furnished the author with the following information, which was of special importance, as this railway had been using a large number of four-cylinder

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* These figures were calculated for a standard quality of coal; they varied after a fixed proportion when other qualities were burned.

† That is—per one hundred metric tons carried a distance of one kilomètre.

(M. Sauvage.)

compounds for several years. He said that, "although the comparison between compound and ordinary locomotives was influenced in practice by the numerous differences of the old and new types of engines, the same advantages were found in actual service and in trials, namely 7 to 16 per cent. economy of fuel, according to the type of engine."

A satisfactory reply to Mr. Dugald Drummond's question (page 429) would involve a complete study of the compound locomotive as compared with the simple one. The author felt flattered by such a question, which however went beyond the scope of his present Paper, which merely intended to give a short account of locomotive design in France. He hoped to be able at some future time to publish such a comparison as that desired by Mr. Drummond. Such a publication would require the careful perusal of a large number of documents and some new experiments. Although very desirous of responding to the great attention paid to his Paper, he felt, after a careful consideration of the question, that at the present time he could give only an insufficient answer to the question.

Mr. Drummond was quite correct in saying that for a fair comparison it was absolutely necessary that the engines should work under similar conditions. But it was very difficult to realise these conditions. There were, in nearly all cases, differences between the locomotives compared, other than the use of simple or double expansion, and in regular service the weights, speeds, and atmospheric conditions frequently varied. It seemed that a really precise study would require special tests in a laboratory, where all conditions might remain unaltered for any length of time, and might be modified one by one. The expense of such experiments would certainly be great, but that difficulty could be easily surmounted if the leading railway companies of one country would agree to contribute for this object of common utility.

Mr. Joy (page 429) had remarked that the saving of 12 per cent., which resulted from the use of four-cylinder compound locomotives, was low when compared with the economy that attended the introduction of the compound system in marine engineering, which no doubt was due to the very variable conditions of locomotive service. The power and speed of locomotive engines seldom remained constant for any length of time. Frequently they worked with a degree of expansion, which was far from being the most economical. A certain waste, which of course was the same with ordinary and with compound locomotives, resulted from periods, sometimes prolonged, when the locomotive fire was standing idle. Greatly enlarging the cylinders of the locomotive, with a view to expanding the steam more completely, seemed hardly practicable in a non-condensing engine, where the pressure at the end of the expansion must in no case fall below that of the atmosphere.

POLYPHASE ELECTRIC TRACTION.

By Professor C. A. CARUS-WILSON, of London.

Part I. of this Paper deals generally with the Polyphase System and its application to railways, with illustrations from the Burgdorf Railway in Switzerland.

Part II. is devoted to a description of acceleration tests made on the Burgdorf Railway, and a comparison of the results with those obtained with continuous-current railway motors at Chicago.

Appendix A contains a detailed account of the action of a polyphase motor, with special reference to its behaviour as a railway motor.

Appendix B contains a description, with criticism, of the polyphase motors used on the Burgdorf Railway.

Appendix C gives the results of some coasting tests made on the Burgdorf Railway.

PART I.

The Polyphase System.

The factors which determine where electricity may be substituted for steam on existing railways with the greatest advantage are too numerous to permit of adequate discussion in a single paper. The author therefore proposes to draw attention to some features of the polyphase system bearing on this question, particularly those relating to punctuality and frequency of train service.

With steam traction it is necessary to make up trains of considerable length in order to meet expenses, hence where the traffic is small the train interval is large. This is felt most on cross-country lines where the long intervals between trains are generally a cause of much inconvenience, not only on account of the poor service it affords between adjacent towns, but also because of the great difficulty of making connections at main line stations. With electric traction, on the other hand, experience has shown that single independent motor-cars, carrying say forty passengers, can be run economically at frequent intervals, so that a line which when worked by steam has, say, a train interval of two hours, when worked by electricity might have trains every half hour. Where cross-country lines, by which stations on the different main lines are linked together, are equipped electrically, they can be provided with a train service many times more frequent than with steam traction, and greatly increased travelling facilities can be offered to the public.

The breaking up of the traffic into small units, rendered possible by the substitution of electricty for steam, besides greatly facilitating cross-country travel, has a marked influence on the punctuality of the train service. The more continuous and uniform movement of the traffic enables the employees of the line to be more uniformly occupied. The infrequent arrival of long trains with large numbers of passengers and corresponding quantities of luggage gives place to more frequent arrivals of single cars, thus enabling the existing staff to handle the traffic with greater promptitude and facility. The more frequent service is thus a more punctual service, since the strain on the staff in keeping the trains running to time is more evenly distributed over the hours of the day, and the work involved in getting each train off is diminished in proportion as the train interval is reduced. The advantage of the new system is most apparent when temporary increases in the traffic have to be handled, as it is on such occasions that the staff is most severely taxed and the consequent unpunctuality most noticeable.

The punctuality of a steam railway is affected not only by the difficulty of handling temporary increases in the traffic at the stations, but also by the influence of such increase on the actual running speed of the trains, particularly on lines where the grades are at all considerable. The same difficulties have to be met in an electric railway, and the problem of maintaining a uniform speed under varying load thus becomes one of great importance.

The continuous-current motor, as generally used for electric railway work, shows a large reduction in speed at heavy loads. Thus in Fig. 28 (page 452) it is seen that when running light with a 16-ton car the speed is 24 miles per hour, and when hauling seven 16-ton trailers the speed is 15 miles per hour. Where such motors are used, it has become the practice to meet temporary increases in the traffic by adding motor-cars each capable of handling its own load. Thus on the South Side Elevated Railway, Chicago, the trains are made up of motor-cars weighing 19 tons, each driven by two 52 horse-power motors, the number of cars depending on the traffic, and varying from time to time during the day. The expense of working the separate motors on each car may be reduced by devices such as Mr. Sprague's Multiple-Unit System, by which one motor man controls all the motors in a train by a single controller. Such systems however involve complications in the controlling arrangements, and large first cost in providing each car with a complete motor equipment.

In the alternating-current polyphase system the motors run at a practically uniform speed entirely independent of load or grade.* Figs. 27 and 28 (page 452) contrast the action of continuous-current and polyphase motors under conditions of varying loads and grades. Thus a railway equipped with polyphase motors can carry a temporary increase of traffic without influencing in any appreciable degree the scheduled speed, the only exception to this statement being that an increase of load affects the time of starting; this will be considered later on. Experiments have been made of which records will be given subsequently, showing no appreciable variation of speed when the load on a motor-car was increased from 32 to 68 tons, and 2 per cent. fall when a 50-ton train ran from a level up a grade of 1 in 40. Hence with the polyphase system a temporary increase in the traffic can be carried by adding trailers to the motor-cars up to the full power of the motors, with no complication of controllers or increase in the working staff, and without any appreciable influence on the speed. The Burgdorf-Thun Railway in Switzerland is a cross-country line worked on this system, and presents so many features of interest illustrating the points which have here been raised, that the author proposes to describe it in some detail.

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* See Appendix A, page 451. The polyphase motor.

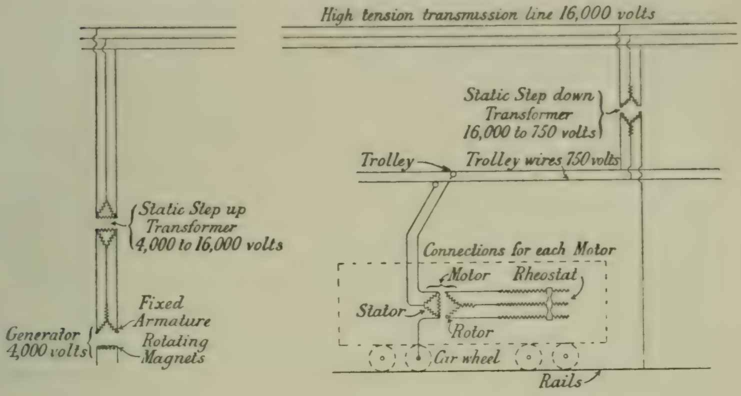
The Burgdorf-Thun Railway.—This line links together three of the main lines radiating from Berne, namely, those to Olten, to Lucerne, and to Interlaken, see Map on Plate 56. The first of these is met at Burgdorf, the second at Konolfingen, and the third at Thun. From Burgdorf to Hasle the line runs side by side with the main line to Lucerne. At Burgdorf connection is also made with Solothurn. The distance from Burgdorf to Konolfingen is 16 miles and from Konolfingen to Thun is 9 miles, making the whole line 25 miles in length. The line is of normal gauge, and carries the ordinary rolling stock of the other Swiss railways to which it is connected. It is worked entirely by electricity on the polyphase system, the power house being situated at Spiez at a distance of 5 miles from Thun. A plan of the line is given on Plate 57, and a profile on Plate 58. The train service is shown by the time schedule which is given in Fig. 5, Plate 59. From Burgdorf to Thun there are eleven trains daily, and twelve from Thun to Burgdorf. From Thun to Konolfingen there are fifteen trains daily, and fourteen from Konolfingen to Thun. Each train generally consists of one motor-car and one trailer, together capable of seating about 100 passengers. Some of the above-mentioned trains are supplementary trains, running at about ten minutes headway; these are shown in the time schedule by dotted lines.

The Electrical Connections.—These are represented diagrammatically in Fig. 25 (page 439). The generators in the power house at Spiez generate current at 4,000 volts, which is transformed to 16,000 volts in the step-up transformers. The current is carried at this tension from the power house along three overhead copper wires of 5 millimetres diameter to the step-down transformers situated at intervals of two miles along the line between Thun and

Burgdorf, Plate 57. The current is here transformed down from 16,000 volts to 750 volts, and carried from thence to the two hard copper trolley wires, 8 millimetres diameter, and to the rails forming the third wire. From the trolley wires two sliding contacts convey the current to the stator of the motors, the third connection being through the wheels of the carriages. The rotors of the motors are provided with rheostats and sliding contacts for purposes of control.

BURGDORF-THUN RAILWAY.

Fig. 25. *Diagram of Electric Circuits.*


High tension transmission line 16,000 volts
Static Step down Transformer 16,000 to 750 volts
Trolley
Trolley wires 750 volts
Static Step up Transformer 4,000 to 16,000 volts
Connections for each Motor
Motor
Rheostat
Stator
Rotor
Fixed Armature
Generator 4,000 volts
Rotating Magnets
Car wheel
Rails

The Passenger Motor-cars.—A general view of one of these cars is given in Fig. 11, Plate 61. Details of the construction are shown in Plate 62. The main frame is 49 feet long and 6 feet 6½ inches wide. The distance between the centre line of the bogies is 31 feet. The wheel base is 7 feet 2½ inches. The car, when completely equipped, weighs 32 tons empty, and has seating capacity for 66 passengers. Each bogie is provided with two motors, geared to the driving axles of the car. A general view of one of the bogies is given in Fig. 12, Plate 61, and details of the method of suspending the motors on Plate 63. There are 83 teeth in the spur wheel, and 28 in the pinion, giving a gear ratio of 2·96. The diameter of the driving wheel is $40\frac{5}{32}$ inches when new. The trailers used are of lighter construction than the motor-cars, and weigh 12 tons. Each motor-car is fitted with one of Messrs. Peyer and Favarger's tachygraphs, for recording automatically the speed of the car.

The Motors.—These are of the three-phase type, with eight poles, and designed to give 64 brake-horse-power each when connected to a line having a tension of 750 volts and a frequency of 40. The speed of synchronism of the motor is 600 revolutions per minute, making the speed of the car 35·5 feet per second, or 24·2 miles per hour, or 39 kilomètres per hour.* The torque curves for these motors with different rotor resistances are given in Fig. 34 (page 457), showing the resistance per phase that has to be put in the rotor circuit to obtain any required speed. The action of the four motors is regulated by either of the two controllers, that in the forward vestibule being the one generally used. The four stators are connected in parallel, while the four rotors are each connected to four rheostats placed under the body of the car, and electrically independent of one another. The rheostats are worked simultaneously by rods and mitre gear from the controllers, as shown on Plate 62. The first motion of the controller connects the stators to the line and puts the full resistance in the motor circuits. The subsequent motions gradually take out the resistances, leaving the rotors short circuited.†

Automatic Speed Record.—The speed curve of the 3.41 train from Burgdorf to Konolfingen is shown on Plate 64, which was taken with one of the tachygraphs with which the motor-cars are fitted. Vertical distances represent speeds in kilomètres an hour; the distance between the horizontal lines is not intended to be equal. The points above and below the record give the time in minutes. On leaving Burgdorf a sharp curve and rise of 1 in 100 reduces the acceleration, which would otherwise be uniform up to full speed, as explained above. Maximum speed is 39 kilomètres or 24·2 miles an hour, and is kept practically constant, the slight variations being caused by irregularities in the track, and varying curves and grades. On leaving Oberberg the record shows where the train left the level and passed on to the grade of 1 in 143, thus making the acceleration curve slightly bend over; the same thing is shown in other places. This record is particularly interesting as showing the actual variations in speed when going up and down the steepest grade on the line. The first part of the distance from Biglen to Gross-Höchstetten is an up grade of 1 to 40; this is followed by a short level stretch and then by a down grade of 1 in 40. The record clearly shows the slight reduction in speed, 2 per cent., on climbing the up grade, then the return to 39 kilomètres an hour on the level, and the slight increase of speed, 2 per cent., on descending the grade of 1 in 40. On leaving Gross-Höchstetten the acceleration curve is markedly increased when the train gets on to the grade of 1 in 40.

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* See Appendix B, page 456. Particulars of the motors used on the Burgdorf Railway motor-cars.

† The whole of the electrical equipment of this line was designed, constructed and erected by Messrs. Brown, Boveri and Co., of Baden, Switzerland.

The Grades.—These are excessive, and have an important influence on the working of the line. The 32-ton motor-cars are each equipped, as explained above, with four 64 horse-power motors. These are able, when acting together, to drive the motor-car itself, and one 12-ton trailer up the maximum grade of 1 in 40. If the maximum grade on the line had not exceeded 1 per cent., four more 12-ton trailers, making five in all, might have been added when occasion required. Thus in attempting to reduce the expense of construction by admitting steep grades, the usefulness of the electrical equipment has been seriously affected. The general impression that it makes no difference how steep the grades are on an electrically driven line has in this case led to the adoption of such grades as largely to nullify the valuable property of polyphase motors referred to. The practical effect of the grades on the working of the line is that when the capacity of the train has to be increased beyond that afforded by one motor-car and one trailer, in order to deal with a temporary increase in the traffic, a second motor-car and trailer have to be added.*

Influence of the Starting Period.—From what has been said above, it might appear that the best results on a line such as that from Burgdorf to Thun would be obtained if the track were absolutely level, but this is not the case, since the motors have to be able to exert an abnormal effort in order to start the train, and this effort may be utilised in mounting a grade. Thus the maximum permissible grade depends upon the effort required to start. The ability of polyphase motors to accelerate, and their economy in so doing, are thus matters of importance, and the author has therefore made a number of tests on the Burgdorf Railway with a view to obtaining definite information on these points. An account of the tests is given later in this Paper.† Some of the results will be quoted here. Allowing 94 per cent. as the efficiency of the gearing at full load, the actual horizontal effort of the motor-cars on the Burgdorf Railway, at 60 kilowatt input, is 3,500 lbs., from which has to be deducted the axle and track resistance of the motor-car itself; taking this at 15 lbs. per ton of load, for both motor-cars and trailers, we find that a single 32-ton motor-car will get up full speed, 24·2 miles per hour, in 26 seconds. The time observed in the tests was 30 seconds. The addition of one trailer will increase the time of getting up speed to 38 seconds. Two trailers should by calculation take 51 seconds, the test gave 57; three trailers should take 67 seconds, the test gave 71. Five trailers would take 106 seconds to get up speed. The discrepancy between calculation and test is probably due to the resistance to motion having been taken too small.

In Table 1 are given the number of trailers which can be drawn up different grades by one motor-car; also the corresponding acceleration with full load on a level, and the difference of time due to starting with maximum load as compared with the motor-car only.

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* The makers of the electrical equipment were not responsible for this course.

† See Part II, page 445. Acceleration Tests on the Burgdorf Railway.

TABLE 1.—*Showing time lost in starting (calculated).*

Grade.	No. of 12-ton Trailers.	Total Maximum Weight. Tons.	Acceleration f. p. s. per second.	Time lost in starting. Difference between maximum and minimum load.	
				1 station. Seconds.	14 stations. Minutes.
1 in 40 .	1	44	0·92	6	1·5
1 in 62 .	3	68	0·52	20	4·5
1 in 100 .	5	92	0·33	40	9
1 in 200 .	8	128	0·17	87	20

It will be seen that as the maximum grade is reduced the maximum possible load is increased, but at the expense of a considerable increase in the time lost in starting. Thus five trailers could be hauled up a grade of 1 to 100, but nine minutes would be lost in starting. This would probably be inadmissible, in view of the necessity of making connections with the main lines. If five minutes is fixed as the maximum permissible starting delay, a load variation of three trailers could be dealt with, and this would mean a maximum grade of 1 in 62. In general, the maximum permissible starting delay should be fixed first; this determines the number of trailers, and this again the maximum grade. The fewer the stops, the larger will be the number of trailers, and the smaller will be the maximum grade.

In considering the application of electricity to existing railroads, the grades and station intervals are of course fixed. The average station interval in this country is probably greater than that on the Burgdorf Railway, which is one mile and three-quarters, and the grades would not be so steep. If one assumed 3 miles as the average station interval, and 1 in 100 as the maximum grade, on a line 25 miles long, a motor-car with an electrical equipment of 250 horse-power could haul a maximum of five trailers, or a total train weight of 92 tons, with a time difference of only five minutes between minimum and maximum load.

The Goods Traffic.—On the Burgdorf Railway the goods traffic is hauled by locomotives specially designed for the purpose, as shown in Fig. 10, Plate 61, each of 300 horse-power; these can haul a total maximum train weight of 50 tons at full speed up the steepest grade of 1 in 40. Details of the motors are given in Plate 60. The locomotive itself weighing nearly 30 tons leaves only 20 tons for the weight of the train; hence it has been found necessary to reduce the speed of the locomotives by gearing, see Fig. 9, Plate 60, so that they can run at half speed, and thus draw loads of 70 tons up the steepest inclines, the total train weight then being 100 tons. The time schedule of the goods trains is shown in Fig. 5, Plate 59. A reference to Table 1 (page 443) shows that if the steepest grade had been 1 in 100 instead of 1 in 40, as at present, the same locomotives could either (1) carry a train of 100 tons at full speed, or (2) a train of 200 tons at half speed. The influence of the existing grades on the carrying power of the locomotives has already been found to be a serious drawback. It may however be questioned if it is wise to use locomotives for hauling goods on such a line, since their use means so large a percentage of dead weight. The motor-cars weigh about the same as the locomotives, carry 66 passengers, and can haul 60 tons behind them up a grade of 1 in 100. Supposing the average passenger load to be one motor-car and two trailers, making 56 tons, there remain 36 tons which might be made up by goods. Since there are twelve trains per day one way, the motor-cars have a goods carrying capacity of 430 tons, or six times that of the existing locomotives. It would seem therefore that there is much to be said in favour of combining goods and passenger traffic on such a railway.

PART II.

Acceleration Tests on the Burgdorf Railway.

In September 1899 a series of tests were carried out at Konolfingen, under the author's direction. The tests, which had to be made during the intervals between the passing of the regular traffic, were conducted on a motor-car to which trailers could be attached.

The method of conducting a test was as follows:—One of the engineers of the line took charge of the controlling apparatus and acted as motor-man. In the forward vestibule an assistant gave the time from a stop-watch to an observer who noted the ammeter reading at each instant. In the rear vestibule a second assistant gave the time from a stop-watch, while one observer noted the voltmeter reading, and another took the reading of a speed indicator. Two men were told off to keep a look-out and announce points passed on the track, such as grade posts, &c. The speed indicator made a continuous automatic record of the speed, which was detached and numbered after each test. The motor-man signalled the start, at the same moment throwing over the controller, so as to give the motors the maximum current, which was maintained constant as long as possible. The readings of all instruments were taken at five-second intervals from the moment of starting, and one voltmeter reading was taken immediately before starting. Each observer recorded his own observations, and filled in those of the other observers after every test. The car was allowed to proceed for some distance after full speed had been reached, the current was then cut off, the brakes put on, and the car brought to a standstill. Three sets of experiments were made, (1) with the motor-car only, (2) with the motor-car and two trailers, (3) with the motor-car and three trailers.

Method of Deducing Results.—The apparent power input, obtained by multiplying together the instantaneous values of the voltmeter and ammeter readings, was plotted in kilowatts as a curve on a time base, Plate 65, and continued up to the point at which full speed was reached, as shown by the speed indicator readings, which were plotted on the same base. The power factor for any given watt input, being independent of the rotor resistance, is the same as when the motor is running synchronously with an equal input and with short circuited rotor, and can be found from the curve given in Fig. 33 (page 457). The true watt input was thus obtained and plotted beneath the curve of apparent watt input, the area enclosed by the curve giving the energy expenditure in watt hours up to any given time. The weight of the train being known, the number of watt hours per ton expended in bringing the train to full speed was then determined. In all the tests the experimental train started at the point shown in Fig. 4, Plate 59, and moved in the direction of Burgdorf, thus encountering successively a 300-mètre curve, a main line crossing, and a second 300-mètre curve. After starting, the train ran for a distance of 1,700 feet on a level before reaching the grade of 1 in 47.

Criticism of the Tests.—Three sets of experiments were made with different trains, namely, one set of four tests with one motor-car and three trailers, the total weight being 68 tons; one set of three tests with one motor-car and two trailers, the total weight being 56 tons; one set of two tests with the motor-car by itself, the total weight being 32 tons. The observations obtained in two tests out of each set have been plotted and are given on Plate 65. The automatic speed curves are given in Plate 66, with the exception of Test No. 5, of which the record was spoiled. At the time the tests were being conducted the automatic regulators governing the motion of the turbines in the power house at Spiez were being overhauled, and consequently out of action, the governing being performed by hand. The result was that the speed of the generator, and hence the frequency, varied considerably, and this was shown in a variation of the speed of the train when full speed had been reached.

The variations in the power input are due in part to irregularities in handling the controller, but the most important variation is caused by the large drop that takes place in the tension. The transformer stations are about two miles apart, and the tests were conducted on a portion of the line about midway between two stations, and therefore at a point where the drop is a maximum. The effect of the drop is shown in the diminished input and the consequent reduction of torque and acceleration at the moment of starting, resulting in an energy expenditure about ten per cent. more than would be required if the tension were kept constant. The speeds given in Plate 65 were obtained from the indicator readings in all cases but that of Test No. 3, where they were deduced from observations made from dropping clay balls on the track at noted time intervals and afterwards measuring up the corresponding space intervals. In Test No. 1 the motors were switched off before full speed had been reached. In Test No. 7 the trolley jumped off the overhead wire when the car struck the main crossing, causing a drop in the power input and in the acceleration.

The Results of the Tests.—The areas of the true power curves in Tests 3, 6, 8 and 9 have been calculated up to the point at which a speed of 23 miles per hour, or 33·6 feet per second was reached, and the areas of the curves in Tests 8 and 9 have also been calculated up to 24 miles per hour, or 35·2 feet per second. The results are given

TABLE 2.—*Acceleration Tests.*

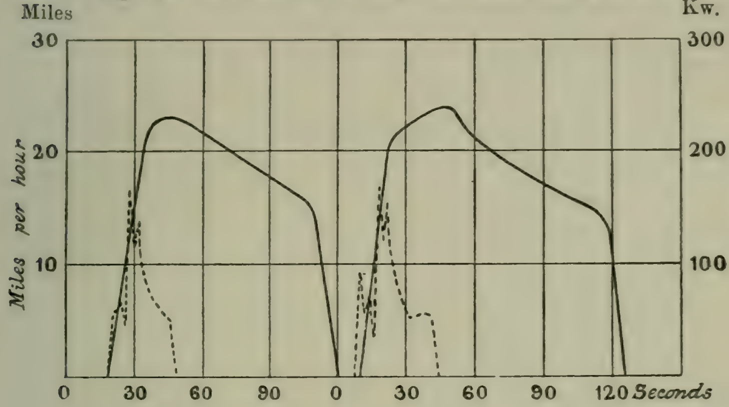
Railway.	Test Number.	Maximum speed m. p. h.	Weight of Train per Motor. tons.	Acceleration f. p. s. per second.	Time to full speed. seconds.	Maximum K.W. input per motor.	Watt-hrs. per ton.	Watt-hrs. per motor.
Burgdorf Railway . (polyphase)	3	23	17	0·48	70	50	52·6	896
,, ,,	6	23	14	0·60	56	55	52·8	741
,, ,,	8	23	8	1·20	28	53	41·5	332
,, ,,	9	23	8	1·08	31	53	48·8	391
,, ,,	8	24	8	1·17	30	53	45·1	361
,, ,,	9	24	8	1·07	33	53	53·2	425
Chicago Railway . (continuous current)	—	23	9·5	1·12	30	75	34·7	330
,, ,,	—	24	9·5	0·95	37	75	39·5	375

in Table 2 (page 447). The energy expended per ton of load moved increases with the number of tons per motor. The reason of this is that the energy is proportional to the time occupied, and the time increases in a greater ratio than the load. Thus if the load per motor is increased by 75 per cent. the time is increased 100 per cent. and energy per ton 14 per cent. This shows the importance of ample driving force, and the value of high initial acceleration in obtaining good efficiency. The best results were obtained in the tests with the motor-car alone, when each of the four motors had to move a weight of only 8 tons, and of these results the lowest energy expenditure was observed in Test No. 8, where 41·5 watt-hours per ton was the energy expended in getting up a speed of 23 miles per hour. With the motor-car and two trailers, giving a weight of 14 tons per motor, the energy expenditure rose to 52·8 watt-hours per ton. In calculating these results, the power factor has been taken rather too large, so that the actual energy expenditure is somewhat lower than the values given above, see Appendix B (page 456).

Comparison of these Results with those obtained with Continuous Currents.—One of the most recent continuous-current railway equipments is that installed on the South Side Elevated Railway at Chicago, a full account of which was given in a paper read by Mr. F. J. Sprague before the American Institute of Electrical Engineers on May 16th 1899. The trains on this railway are made up of motor-cars operated on the Sprague Multiple Unit System. Each car weighs 19 tons and is equipped with two motors making 9·5 tons per motor. The diameter of the driving wheel is 33 inches; there are 65 teeth in the spur wheel and 22 in the pinion, making the gear ratio 2·95. The tension of the line is 650 volts at the switchboard and 600 at the cars. The motors, made and installed by the General Electric Company, are rated at a maximum output of 52 horse-power at 500 volts, though in practice they are driven considerably beyond this, the maximum horizontal tractive effort actually exerted being 1,900 lbs. Series-parallel control is used. To compare the weights of the cars in the two cases, we may note that each motor-car on the Burgdorf Railway weighs 32 tons and carried 66 passengers, giving 1,070 lbs. per passenger. Each car on the Chicago Railway weighs 18·2 tons and has seats for 40 passengers, giving 1,020 lbs. per passenger, so that there is but little difference between the two equipments in this respect.

A complete series of tests was made at Chicago on September 3rd 1898, and is described fully in the paper referred to above. The results of two of these tests, which are typical of the rest, have been inserted in Table 2 (page 447), while the curves are given in Fig. 26.

Fig. 26. *Acceleration Tests with Continuous-Current Motors.*



It will be seen that the continuous-current equipment can get up a speed of 23 miles per hour with 34·7 watt-hours per ton in 30 seconds as compared with 41·5 watt-hours in 28 seconds with the three-phase equipment. Similarly, the continuous-current motors get up 24 miles per hour with 39·5 watt-hours in 37 seconds, as against 45·1 watt-hours in 30 seconds for the three-phase motors. Thus for the lower speed the continuous-current motors use 84 per cent. of the energy used by the three-phase motors, while for the higher speed the proportion is 87 per cent., while in the latter case the three-phase motors get up full speed in 81 per cent. of the time taken by the continuous-current motors. The reduction of energy in the continuous-current motors is due to the use of the series-parallel controller, compare Fig. 30 (page 453).

Comparing the maximum power input in the two cases, it will be observed that the power curves of the continuous-current equipment show a maximum of 150 kilo-watts for two motors, or 75 kilo-watts per motor, as against 53 kilo-watts per motor in Test No. 8 with the three-phase equipment. In some of the tests made at Chicago the maximum input reached 90 kilo-watts per motor, but this was because the controller was not properly handled. The large majority of the tests gave 75 kilo-watts as the maximum power input. It thus appears that the maximum power input as obtained in actual practice with the three-phase motor is only 70 per cent. of that with the continuous-current motor.

Conclusion.—The tests described above were made with the object of ascertaining the ability of polyphase motors to get up speed under ordinary conditions of railway service, and the economy obtainable in so doing when compared with that observed with the best continuous-current motors. The results of the tests go to show that polyphase motors are admirably adapted to getting up speed, and that the acceleration can be maintained uniform up to full speed. A comparison of the results with those obtained with one of the best and most complete continuous-current equipments shows that there is very little difference between the two in economy of starting. The continuous-current motors have a slight advantage in the amount of energy expended, while they occupy a longer time in reaching high speeds and require larger maximum power inputs than the polyphase motors.

The author wishes to record his indebtedness to the following gentlemen for assistance rendered during the tests :—Mr. K. Krähenbühl, Engineer of the Burgdorf-Thun Railway; Dr. E. Blattner, Professor at the Technical College at Burgdorf; Messrs. E. Thomann, J. Landolt, H. Morgenthaler, and M. G. S. Swallow, Engineers at Messrs. Brown, Boveri and Co. He would also like to express his thanks to the firm of Messrs. Brown, Boveri and Co. for the kind way in which they have provided him with data and information, and also to the Management of the Burgdorf-Thun Railway, who afforded every facility for making the tests.

The Paper is illustrated by 12 Plates, Nos. 56–67, and the Figs. in the text.

APPENDIX A.

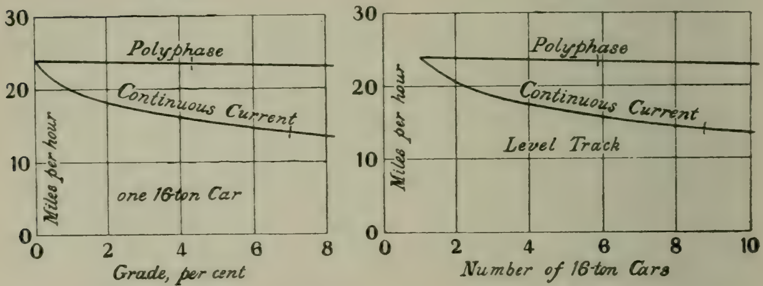
The Polyphase Motor.

The action of a polyphase motor may be likened to that of a continuous-current motor in which both the fields and the armature are capable of rotation. Supposing the fields of such a motor to be fully excited, and rotating at full speed with the armature at rest, a current of any desired magnitude may be induced in the armature by simply short-circuiting it, since the generation of a current depends simply on the relative motion of the fields and the armature. The torque produced by the action of the fields on the induced current will tend to turn the armature, and if the fields be kept rotating at a uniform rate, the armature will speed up until the relative motion of the fields and the armature is sufficient to generate a current that exactly balances the load; uniform speed has then been reached. The slip, or the difference between the speed of the armature and the speed of the fields, is generally stated in per cent. of the speed that would be reached if the load were nothing, that is, if the armature were rotating at the same speed as the fields. This speed is spoken of as the speed of synchronism. In a polyphase motor the rotation of the field is produced by magnetising the fixed part, or stator, by two or more alternating currents in such a way that the resultant magnetic field rotates at a uniform speed. In the motors used on the Burgdorf Railway three alternating currents are used differing in phase by 120°. One great advantage of such a motor over the continuous-current motor is found in the absence of a commutator, for the current in the armature, or, as it is called, the rotor, can be induced by short-circuiting its coils through a simple form of slip ring, the current from the line being led directly into the stator without any moving contacts. Plate 67 shows the rotor and the stator of a 150 horse-power polyphase motor.

Clearance.—In a polyphase system the ratio of the current usefully employed to that generated, as measured by the power factor, depends mainly upon the width of the space between the fixed and moving parts of the motor. Hence it is of great importance to reduce the clearance to the smallest limit consistent with safety. Thus the 64 horse-power motors on the Burgdorf Railway have a clearance of 1·5 millimètres on a radius and the 150 horse-power motors have a clearance of 3 millimètres. This necessitates very careful construction, and special precautions have to be taken to prevent any chance of contact between the rotor and the stator. Plate 60 gives the details of the construction of the 150 horse-power motors on the Burgdorf Railway. Some mechanical engineers consider the necessity of such a small clearance to be a fatal objection to the use of polyphase motors on railways, but experience shows that such motors can be constructed to run continuously without accident.

*Comparison of Continuous-Current and Polyphase Motors.**

Fig. 27. Fig. 28.



Variation of Speed with Load.—In a polyphase motor the speed is practically independent of the load. Thus the 64 horse-power motors on the Burgdorf Railway run at full load with a slip of only 1·8 per cent. This is in marked contrast to the action of a continuous-current series-wound motor, such as is generally used on electrical railways, in which a reduction of speed of 40 per cent. from no load to full load is not uncommon. Figs. 27 and 28 show the speed variation of the Burgdorf motor compared with that of a standard continuous-current motor, firstly with constant load and varying grade, secondly with level track and varying load. The polyphase motor maintains the speed at the expense of a corresponding amount of power, while the continuous-current motor economises power at the expense of speed, as shown in Fig. 29.

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* The short line cutting each of the curves in Figs. 27, 28, and 29, represents the point of maximum rated load in each case.

Comparison of Continuous-Current and Polyphase Motors.

Fig. 29.

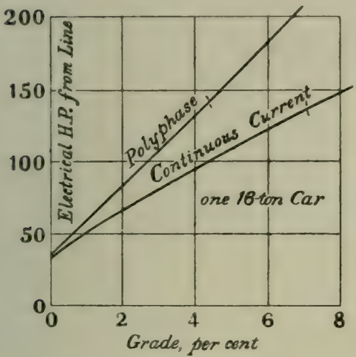
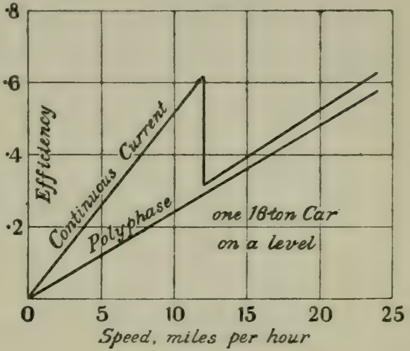


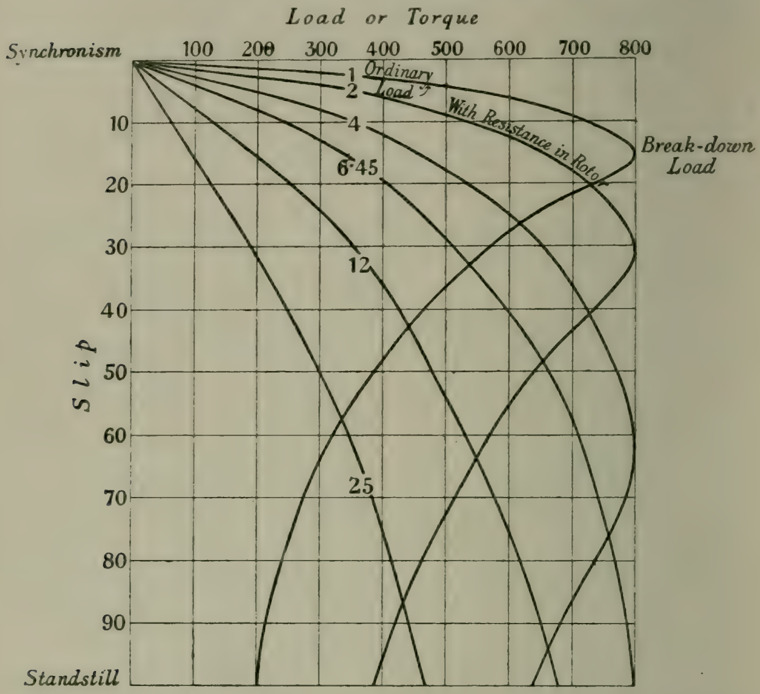
Fig. 30.



Maximum Load.—In Fig. 31 (page 454) is given the variation in speed from standstill to synchronism of a polyphase motor with different loads. Following the curve marked 1, it will be noticed that as the load increases the speed gradually decreases, until for a load of 300, for instance, the slip is 2 per cent. As the load still further increases, the speed falls off in a greater ratio, until the maximum load of 800 is reached, where the slip is about 15½ per cent. This is the breakdown load. If the load be increased beyond this the motor cannot recover itself, and is brought to a standstill. In practice the maximum working load should not exceed 50 to 60 per cent. of the breakdown load. Thus in the Burgdorf motors the maximum working load is 1·8 of the normal.

Speed Regulation.—If a resistance be placed in the circuit of the rotor so as to increase the total resistance, say, to double it, the action of the motor will be represented by the curve lettered 2 in Fig. 31, in which the slip for equal torque is double what it was with the original resistance. The maximum torque is the same as before but takes place with a slip of 31 per cent. instead of $15\frac{1}{2}$

Fig. 31. *Load Curves of Polyphase Motor.*

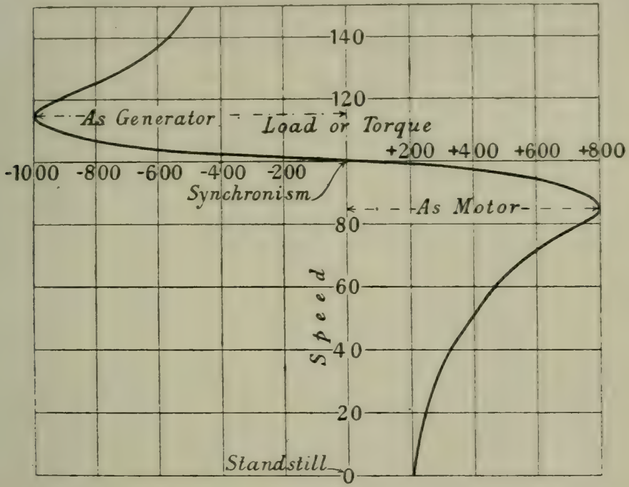


per cent. Thus with any load any required speed can be obtained by merely altering the rotor resistance. The polyphase motor is therefore capable of perfect speed regulation for all loads.

The efficiency at reduced speed is of course less than that at full speed on account of the heating of the rheostats. The polyphase motor herein resembles the continuous-current motor, but it is at this disadvantage, in comparison, that it is not possible to couple two polyphase motors together in the way that two continuous-current motors can be coupled in the series parallel method of control. The superiority of the continuous-current motor in this respect has however been somewhat overstated, seeing that it is only for speeds less than half of full speed that the motors can be put in series. This point is illustrated by Fig. 30 (page 453), which gives the comparative efficiency at equal load and different speeds of a polyphase and continuous-current equipment. For heavier loads the advantage of the latter would be reduced.

Action when descending a grade.—The speed curve No. 1, in Fig. 31, is reproduced in Fig. 32, and continued in order to show

Fig. 32. *Curve showing Braking Action of Polyphase Motor.*



the action of a polyphase motor when driven above synchronism, as, for instance, when a train is descending a grade. It will be seen that as the speed increases above synchronism a negative torque is applied, and the motor acts as a generator, returning current into the line and thereby retarding the motion precisely as if mechanical brakes were being applied. The maximum torque that can be thus applied is greater than its breakdown torque as a motor, but the slip at the maximum torque is the same. This is a feature of great importance, for not only does the polyphase motor act as an efficient brake in descending a grade, but the energy of the descent is returned into the line and is available for driving other trains. Thus, on the Engelberg Railway, which is a mountain railway worked by polyphase motors, the trains descend a 25 per cent. rack grade held only by the brake action of the motors, which keeps the speed at four per cent. above synchronism; part of the current delivered into the line drives another train up a 5 per cent. grade, the remainder being used up in a rheostat.

Starting.—From Fig. 31 (page 454) it will be seen that there is a certain rotor resistance corresponding to standstill with maximum torque, in this case twenty-five times as much as the resistance of the rotor itself. If the rotor resistance has this value at the moment when the motor is connected to the line, it will start with its maximum torque. If the resistance is taken out of the circuit as the motor speeds up, the torque can be maintained constant and equal to the maximum starting value up to full speed for that load. In other words, the torque and therefore the acceleration can be maintained constant practically up to full speed. It follows that the speed curve of a train driven by polyphase motors shows uniform acceleration up to full speed. Compare the speed curves given on Plate 64.

APPENDIX B.

Particulars of the Motors used on the Burgdorf Railway Motor-Cars.

The stator winding consists of 51 turns per phase and is connected up in mesh. When hot, the short-circuited resistance of the winding per phase is 0·71 ohm. The rotor winding consists of 8 turns per phase, and is connected up in star, the short-circuited resistance per phase being 0·0135 ohm hot. The characteristic features of the motors are well shown by the curves given in Fig. 33. These were obtained by brake tests made with motors of the same type as those used on the Burgdorf Railway, and differing from them only in the width of the clearance, which was 1·25 millimètres, as compared with 1·50 millimètres in the Burgdorf Railway motors. Owing to the low internal resistance the speed is very uniform, the slip at full load being only 1·8 per cent. For the same reason the efficiency at full load is high, namely, 92 per cent.

The large value of the apparent watts at no load indicates a large magnetising current, amounting to 24 ampères, or 28 per cent. of full load current. The good efficiency at full load, however,

Fig. 33. *Test Curves of 64 Horse-power Polyphase Motor.*

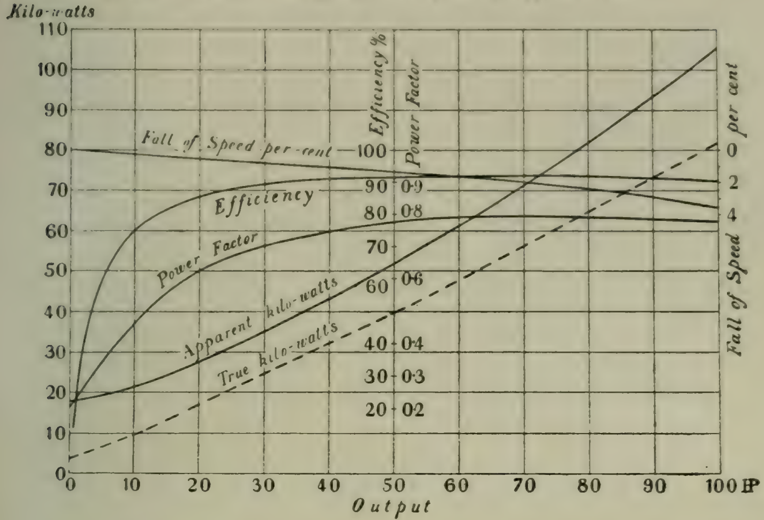
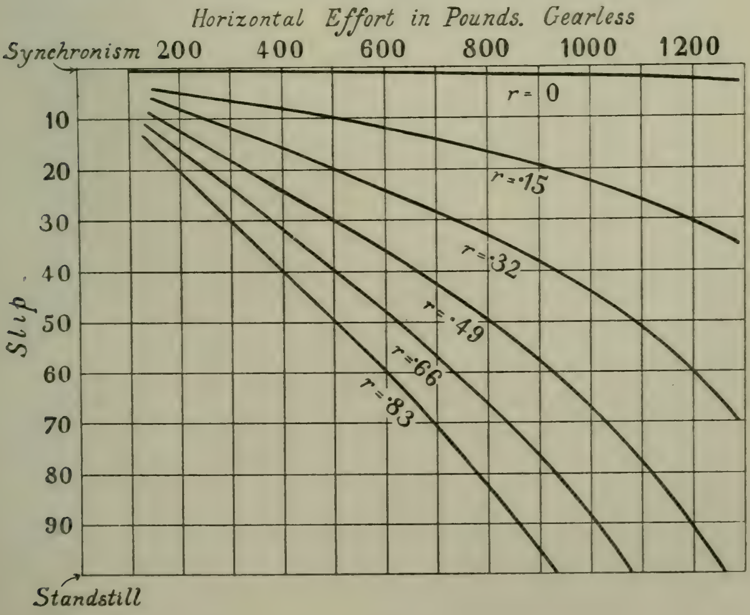


Fig. 34. *Load Curves of 64 Horse-power Polyphase Motor.*



shows that the wattless component is a more important element in the magnetising current than the hysteresis component, in other words, that the predominant factor in accounting for the large no-load current is the width of the clearance. This is further evidenced by the rapid rise of the efficiency curve, giving relatively good efficiencies at light loads. The large wattless component also influences the form of the power factor curve, making it rise very slowly at first and reach its maximum at about full load. The wider clearance in the Burgdorf motors will, of course, influence the form of the power factor curve, lowering it throughout its length. Hence the values of the true watts obtained by taking the power factors given in the curve sheet will be too high. This must be borne in mind when the results of the tests are considered.

APPENDIX C.

Coasting Tests with Polyphase Motors.

In Fig. 22, Plate 66, are given the automatic speed curves obtained by bringing a single motor-car up to full speed and then allowing it to coast, with the current cut off, before applying the brakes. The data of these tests are given in Table 3.

TABLE 3.—*Coasting Tests on the Burgdorf Railway. One Motor-car of* 32 *tons.*

Curve Letter.	a	b	c	d
Starting time . . .	0′ 00″	0′ 00″	0′ 00″	0′ 00″
Current switched off after .	0′ 25″	1′ 0″	0′ 59″	0′ 30″
Stop	1′ 00″	2′ 10″	1′ 55″	0′ 75″
Distance travelled mètres	500	1100	900	600
Gradients	1 in 113 up	level	1 in 113 up	level
Starting current for 4 motors, in ampères . per phase	240	240	240	250

Discussion.

The Chairman said that unfortunately there was no time to discuss Professor Carus-Wilson's Paper, but he might state that there would be another electric Paper read at the next Session which would afford an opportunity of discussion whether the polyphase- or the continuous-current system was best. He would therefore simply ask the Members to pass a hearty vote of thanks to Professor Carus-Wilson for his very able Paper.

Communications.

Mr. Sydney F. Walker wrote that he considered Professor Carus-Wilson's Paper was a very valuable contribution to the literature of Electric Traction. Up to the present, one rule had held good for that work, namely, series-wound continuous-current motors, working at a line pressure of approximately 500 volts; and the very quality for which Professor Carus-Wilson claimed advantages on the part of a polyphase service, its uniform speed, had been one ground for objecting to its use. Uniform speed was not wanted, but a speed that could be controlled at will. He thought that Professor Carus-Wilson's careful tests, and the Tables which accompanied them, would dissipate a good deal of the prejudice that had existed against a polyphase service.

A continuous-current motor would stand overloading, if current were supplied to it, right up to the point where either its insulation burnt up, or some part of its arrangement for transmitting the power mechanically to the driving axles broke down. It was the case of the willing horse. A polyphase motor was more like the animal, or the man, who had to be coaxed if more than his normal work was required of him; but under no circumstances, under present structural conditions, would he go beyond a certain overload. It

(Mr. Sydney F. Walker.)

was an open question which was of most advantage, not to be able to press the motor to structural break-down point, or not to be able to accomplish certain work, under certain conditions, where it might be of importance to do so, even at the cost of the insulation of a few motors.

The difference was very similar to that which existed between a town electric tramway service and a town electric lighting service.

A tramway manager would risk all to carry every available passenger, even if he had to keep the whole staff on repairs the whole of the succeeding night, to be ready for the following morning, and would provide spare parts of everything for the purpose; and it was sound business on his part to do so. The lighting manager, on the other hand, must have before his mind the absolute necessity of an absolutely constant service, day and night, whether there were many lights on or few, and he therefore could not afford to have his machinery unduly strained. The author mentioned that it was thought that grades did not matter where electricity was the propelling agent. He himself thought that grades were necessarily not of so much consequence where one could call up what power one desired, within the limits of the capacity of the motors and the energy available at the generating station, as where all the usable energy is carried on the train. He thought the question in each case must finally be one of finance. The interest on the cost of the reduction of gradients, plus any additional cost of up-keep of the line that might be incurred, was to be set against the cost of the additional energy consumed and any loss that might be incurred owing to inability to deal with certain traffic at certain times.

Another point which Professor Carus-Wilson raised was the arrangement of the train service. Mr. Sprague had made a good record on the South Side Elevated Railway at Chicago, with what he had termed the multiple-unit system, in which each car or each pair of cars was fitted with a pair of motors, and the cars were connected up into trains of the length required at different times, or portions were disconnected where required, and themselves found their way, propelled by their own motors, down a branch line or siding. The author preferred the system in which, as in the Burgdorf Railway, the locomotive carried the only propelling apparatus, just as the steam locomotive did; his principal reason being the additional expense of the Sprague system, with its separate cabs, connecting cables, &c. The fact appeared to be however, as in so many other of these questions, that the conditions in the two cases were not the same. On the Burgdorf Railway the presence of the steep gradients rendered it necessary that a large surplus power should be provided, which was conveniently placed on the locomotive. On the South Side Elevated Railway the load was practically dependent on the traffic only, and could therefore be most economically dealt with by adding completely equipped motor cars, as required. He himself was inclined to think that it was very doubtful if there was so much difference in the first cost, when all the items were brought into the account. Again, finance must have the last word in the matter. Mr. Sprague had a higher train efficiency than the Burgdorf Railway. If he had accomplished this by increased first cost, the interest on the additional cost would have to be balanced against the increased cost of energy, owing to the decreased efficiency of the train. Local conditions altered the bearing of certain items in the account. Thus the Americans had a saying that capital was cheap and labour was dear; but this applied to America only. In South Africa, or in India, the terms would have to be reversed. One could afford to waste energy, rather than increase the capital outlay, when the cost of generation was low, as where falling water was the source, or the hitherto wasted gases from the blast-furnace.

The curves that the author gave, showing the government of the polyphase and continuous-current motors, were also of very great interest; but he himself could not help thinking that they would be considerably modified if the continuous-current motors were larger, and also if they were differently wound.

The shunt-wound motor was necessarily a better governor than the series-wound, and the larger the motor for a given work the more perfect was the government, and the smaller the variation of speed with variation of load.

(Mr. Sydney F. Walker.)

Very little use appeared yet to have been made of the compound-wound motor, very perfect self-regulation with practically uniform speed would be obtained with it, though the matter of control would be more complicated. One disadvantage that the polyphase system laboured under was the necessity for two service conductors, as against one conductor with the continuous-current; but against that might be placed the greater convenience for distribution, the ability to use higher tension currents.

Professor Carus-Wilson wrote that in reply to Mr. Walker's communication he would disclaim any attempt to prove that polyphase motors were in all cases superior to continuous-current motors for traction purposes, but that on cross-country lines where punctuality was of prime importance, polyphase motors had features which would be found to be of great value, when the substitution of electricity for steam was seriously considered. The existence of a "break-down" load referred to by Mr. Walker must of course be taken account of, but that was not such a serious objection as might at first sight appear, for two reasons. First, the break-down load was 1·5 to 2 times the rated maximum safe working load, a limit which would fairly cover any temporary overload in practice. Second, the polyphase system admitted of the whole installation, from generator to motor, being worked without any kind of safety or automatic cut-out, even safety fuses being dispensed with if suitable generators were used. Under those conditions an interruption in the train service due to overload was far less likely to occur than with the continuous-current system where safety fuses and automatic cut-outs were essential.

In the Paper the series-wound motor was alone considered for comparison. The shunt-wound motor of course gave excellent speed regulation with varying load, but lacked the useful features which had quite rightly led to the series-wound motor being exclusively employed for traction purposes.

EXCURSIONS.*

On Wednesday Afternoon, 27th June, the following Works were open to the visit of the Members and American visitors :—

Westminster Electric Supply Stations, Davies Street, Oxford Street, and Millbank, Westminster.
London Hydraulic Power Co.'s Pumping Station, Millbank, Westminster.
Colonial Consignment and Distributing Co.'s Australasian Frozen Meat Store, Lambeth.
Doulton and Co.'s Pottery Works, Lambeth.
Maple and Co.'s Shops and Factories, Tottenham Court Road.

In the evening the Institution Dinner was held at the Hotel Cecil, Strand, and was very largely attended, the company numbering about five hundred. In the absence of the President, the chair was occupied by E. Windsor Richards, Esq., Past-President; and the following Guests accepted the invitations sent to them, though those marked with an asterisk were unavoidedly prevented at the last from being present.

His Excellency the American Ambassador, the Hon. Joseph H. Choate, LL.D.; the Right Hon. Lord Alverstone, G.C.M.G., Master of the Rolls; the Right Hon. the Earl of Rosse, K.P., D.C.L., LL.D., F.R.S., Honorary Member; the Right Hon. Lord Claud Hamilton,* Chairman, Great Eastern Railway; General Sir Evelyn Wood, G.C.B., G.C.M.G., V.C., Adjutant-General to the Forces; Sir G. Clayton East,* Bart.; Sir Frederick A. Abel, Bart., K.C.B., D.C.L., F.R.S., Honorary Member; Sir E. Montague Nelson,* K.C.M.G.; Rear-Admiral Arthur K. Wilson, C.B., V.C., Controller of the Navy; Sir Courtenay Boyle,* K.C.B., Permanent Secretary, Board of Trade;

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* The notices here given of the various Works, &c., visited in connection with the Meeting were kindly supplied for the information of the Members by the respective authorities or proprietors.

Sir Andrew Noble, K.C.B., F.R.S.; Sir Alexander R. Binnie, Chief Engineer, London County Council; Mr. Edward Boulnois, M.P., Mr. John F. Wallace, President, American Society of Civil Engineers; Professor W. Cawthorne Unwin, F.R.S.; and Mr. H. L. Doulton.*

American Society of Mechanical Engineers.—Mr. Charles H. Morgan, President; Mr. Robert W. Hunt and Mr. John E. Sweet, Past-Presidents; Mr. Jesse M. Smith, Vice-President; Mr. Gustavus C. Henning, Past-Member of Council; Professor H. M. Howe,* Past-Member of Council; Mr. H. de B. Parsons, Past-Member of Council; Mr. A. W. Robinson, Member of Council; Mr. Norman C. Stiles, Member of Council; Mr. H. H. Suplee, Member of Council; Mr. William H. Wiley, Treasurer; Mr. James Dredge, C.M.G., Honorary Member. Mr. Edward R. Archer, Mr. H. B. Binsse, Mr. L. F. Braine, Professor L. P. Breckenridge, Mr. Alexander E. Brown, Mr. Alexander T. Brown, Mr. E. P. Bullard, Mr. A. H. Carpenter, Mr. Lafayette D. Carroll, Mr. Albert L. Colby, Mr. Harte Cooke, Mr. W. S. Doran, Mr. Napoleon Du Brul, Mr. R. N. Fairbanks, Mr. Clark Fisher, Mr. Edward Flad, Mr. Francis T. Freeland, Mr. P. F. Greenwood, Mr. H. S. Haines, Mr. George W. Hammond, Mr. F. H. Hayward, Mr. H. Wade Hibbard, Mr. E. A. Hitchcock, Mr. William H. Honiss, Mr. G. S. Humphrey, Mr. Charles W. Hunt, Mr. George E. Hunter, Mr. F. A. Johnson, Mr. Charles Kirchhoff, Mr. Gompei Kuwada, Mr. David N. Melvin, Mr. F. J. Miller, Mr. Spencer Miller, Mr. Hugh G. Mitchell, Mr. Frank Mossberg, Mr. J. A. Norcross, Mr. Edward H. Parks, Mr. Francis C. Pratt, Mr. William E. Reed, Mr. Francis H. Richards, Mr. Harry W. Rowley, Mr. Edward K. Sancton, Mr. F. P. Sheldon, Mr. Angus Sinclair, Mr. Albert Stearns, Mr. Ambrose Swasey, Mr. Charles W. Thomas, Mr. John Thomson, Mr. F. Thuman, Professor R. H. Thurston,* Mr. W. Wesley Varney, Mr. Charles Ward, Dr. William Watson, Mr. William R. Webster, Mr. Harry E. Wheeler, Mr. George E. Whitehead, and Mr. Kenneth F. Wood.

Mr. James Mansergh, President-Elect, Institution of Civil Engineers; Sir William C. Roberts-Austen, K.C.B., D.C.L., F.R.S., President, Iron and Steel Institute; Mr. John Shaw, President, Surveyors' Institution; Professor Silvanus P. Thompson, D.Sc., F.R.S., President, Institution of Electrical Engineers; Mr. Henry Hodgson, President, Manchester Association of Engineers; Mr. Thomas Evens, President, South Wales Institute of Engineers; Mr. William Armstrong, President, North of England Institute of Mining and Mechanical Engineers; Mr. Henry Withy,* President, North-East Coast Institution of Engineers and Shipbuilders; Sir H. Trueman Wood, Secretary, Society of Arts; and Dr. J. H. T. Tudsbery,* Secretary, Institution of Civil Engineers.

Mr. Alfred Bache; Professor C. A. Carus-Wilson; Mr. William Gowland;* Mr. R. A. McLean, Auditor; Mr. Basil Slade, Architect; and Mr. J. D. Twinberrow.

The Chairman was supported by the following officers of the Institution:—*Past-Presidents*, Sir Lowthian Bell,* Bart., F.R.S., Sir Edward H. Carbutt, Bart., and Mr. Samuel W. Johnson. *Vice-Presidents*, Mr. John A. F. Aspinall, Mr. Arthur Keen, Mr. Edward P. Martin, Mr. William H. Maw, and Mr. T. Hurry Riches. *Members of Council*, Mr. Henry Chapman, Mr. Henry Davey, Mr. Bryan Donkin, Mr. Edward B. Ellington, Mr. H. Graham Harris,* Mr. Henry A. Ivatt, Mr. Henry D. Marshall, the Right Hon. W. J. Pirrie,* LL.D., Sir Thomas Richardson, M.P., and Mr. A. Tannett Walker.

After the usual loyal toasts, that of "Her Majesty's Forces" was proposed by the Right Hon. the EARL OF ROSSE, K.P., and was acknowledged by Rear-Admiral A. K. WILSON, C.B., V.C., Controller of the Navy, who said that the water-tube boilers had given the ships which possessed them one-half to one knot greater speed than they would have had with cylindrical boilers. That meant greater mobility—the power to evade and to overtake a foe. Undoubtedly the water-tube boiler gave trouble, but it was worth all it cost. In every case in which a ship had broken records, it had been fitted with water-tube boilers. The "Powerful" had lately made a voyage at 20 knots, and the Mediterranean Fleet had just cruised 800 miles at four-fifths speed without a hitch in the machinery. General Sir EVELYN WOOD, G.C.B., G.C.M.G., V.C., also responding to the toast, spoke of the large amount of engineering work that had been done during the war in South Africa in repairing bridges and railways. The Chairman proposed the toast of "Our Guests," which was acknowledged by His Excellency the American Ambassador, the Hon. Joseph H. Choate, LL.D., who said that just such exchange of thought and fellowship as occurred at gatherings like the present were calculated to do more to promote friendship and good feeling of nations than anything else. He assured the Institution of Mechanical Engineers that if they decided to visit America a warm welcome would be accorded to them. In speaking of the progress of invention, he enlarged especially on the genius and achievements of James Watt and George Stephenson, and said that they had been the makers not only of England but of America. Mr. Charles H. Morgan, President of the American Society of Mechanical Engineers, also responded to the toast. The concluding toast of "The Institution of Mechanical Engineers" was proposed by the Right Hon. Lord Alverstone, G.C.M.G., Master of the Rolls, and acknowledged by the Chairman.

On Thursday Afternoon, 28th June, the following works among others were open to be visited:—

City of London Electric Light Co.'s Station, Bankside, Southwark.
London Hydraulic Power Co.'s Pumping Station, Shadwell Basin, Wapping.
Great Eastern Railway Locomotive Works, Stratford.
East London Water Works, Lee Bridge.
John I. Thornycroft and Co.'s Steam Yacht and Launch Works, Chiswick.
Multi-Colour Printing Co., Rosebery Avenue.

On Friday, 29th June, three alternative Excursions were made.

One was by special Palace Steamer "Koh-i-Noor" from London Bridge down the River Thames to Southend and round the Nore Lightship.

Another excursion was made by special train to Staines, and thence by brakes to the Staines Reservoirs Works. After luncheon, by invitation of Mr. Walter Hunter and Mr. R. E. Middleton, Joint Engineers, and by Messrs. Aird and Sons, contractors of the works, the party proceeded down the River in a special steam launch to Hampton, tea being served on board. At Hampton the Pumping Stations of the Joint Water Companies were visited, and the return journey then made by rail.

The third excursion was made by two special dining-saloon trains, kindly provided by Messrs. Willans and Robinson, to Rugby; and during the journey luncheon was served by their invitation. On arrival at Rugby the Members visited the Victoria Works, under the guidance of Mr. Mark Robinson, Chairman, and Captain H. Riall Sankey, Director. Afternoon tea was served in the workmen's mess room, which was appropriately decorated, and the company's Band, composed of employees of the firm, played selections of music during tea. The return journey was made in special dining-saloon trains, in which dinner was served by kind invitation of the firm.

During the afternoon the Thames Iron and Shipbuilding Works at Blackwall were open to the visit of the Members.

In the evening a Conversazione was held at the Institution, which was largely attended.

WESTMINSTER ELECTRIC SUPPLY CORPORATION, DAVIES STREET AND MILLBANK STATIONS.

This Corporation obtained Parliamentary powers in 1888 for supplying electricity in the parishes of St. George's, Hanover Square, and St. Margaret and St. John, Westminster. The area supplied is large, comprising the whole of the above parishes. There are three generating stations, namely, Davies Street, Eccleston Place, and Millbank Street.

Davies Street Station.—This station has a total horse-power of 4,240. The engine room is 88 feet by 46 feet, and is lighted from above. There are two boiler houses, one 72 feet by 43 feet and the other 92 feet by 36 feet. The engines are all Willans and Robinson's high-speed single-acting engines, two are of 80 horse-power each, six of 200 horse-power, and eight of 360 horse-power. All engines are compound and work at a steam-pressure of 150 lbs. per square inch. All the larger sizes are 3-crank engines. The steam-pipes are of steel, and are placed on the walls round the room in the form of a ring, with a stop-valve between each pair of engines. The exhaust pipes are placed beneath the floor. Steam is generated in sixteen boilers, all of the dry-back marine type. Ten of these boilers are 8 feet by 12 feet, with 3-inch tubes and two furnaces. The rest of the boilers are 8 feet 6 inches by 14 feet with 3-inch tubes, and two furnaces. Best Welsh coal is used with hand-firing, no mechanical stokers being used. Forced draught is not used, the chimney being 175 feet in height. Fly-wheel and duplex direct-acting feed-pumps are used. The boiler feed-water passes through exhaust steam heaters between the pumps and the boilers. The dynamos generate continuous current at 200 volts pressure, the larger size having an output of 1,000 ampères. They are shunt-wound and are coupled direct to the engine shaft. All regulating is done by shunt resistances and switches placed on the switchboard.

Millbank Street Station.—The steam-engines and the electrical equipment of this station are the same as at the Davies Street Station. The total horse-power installed is 3,840. A large condensing plant is at present being erected; this consists of one circulating pump, two air-pumps, and two condensers, and is capable of condensing the steam from all the engines. The engine-room consists of an old and a new building, with an opening in the wall to connect the two rooms. The switchboard gallery is placed across the building at this opening. The old engine-room is 56 feet by 34 feet, and the new 52 feet by 48 feet. The boiler-house is 140 feet long, and contains one row of fifteen Babcock and Wilcox boilers. An induced-draught fan is at present being erected, the chimney being found too small for the required work. Above the boiler house is a coal store. Three engines are kept especially for supplying the Houses of Parliament, and there is also a special switchboard for the House mains.

The street mains consist of several systems. Bare copper strip stretched on insulators in culverts is used where room can be obtained under the pavement; cables pulled into iron pipes, and cables pulled into earthenware casings, are also used.

All mains run from the stations for distances of from half-a-mile to one mile, and at these points are connected to the distributing mains. Pilot wires are brought back from these points to the instruments in the stations, the engines and dynamos being regulated by them to keep the pressure constant at the feeding points. The number of lamps supplied from the three stations at the end of 1899 were 421,445 of 8 candle-power.

Dr. Alexander B. W. Kennedy, F.R.S., *Past-President*, is the engineer-in-chief, and Mr. C. Stanley Peach, F.R.I.B.A., the architect.

THE LONDON HYDRAULIC POWER CO., MILLBANK AND WAPPING STATIONS.*

The London Hydraulic Power Company commenced supplying power in 1884, and now controls the largest system of hydraulic-power distribution in existence. The pressure employed is 750 lbs. per square inch, and there are at the present time 120 miles of mains laid in the streets of London. They are all in communication and extend from the docks in the east to Kensington in the west. The largest mains are 7 inches bore, and the smallest 2 inches. About 4,500 hydraulic machines are at present working from the mains. The power is principally used for lifts, cranes, hoists, and presses of various kinds. There are also a considerable number of injector fire-hydrants and motors. The quantity of water being pumped into the mains per week is about 16,000,000 gallons. The pressure is maintained from four central pumping stations situated at Falcon Wharf, Blackfriars; Millbank Street, Westminster; Shadwell Basin, London Docks; and Wharf Road, City Road, on the Regent's Canal. A fifth station has been commenced near the Surrey Docks at Rotherhithe which will bring the horse power provided up to 6,000. The capital expended in London has been to the present time about £700,000. The water used is taken from the river, the docks, the canal, and from wells sunk in the gravel beds overlying the London clay. The whole of the water is filtered before being used. The whole supply is registered through meters, and the charges are made on a sliding scale per 1,000 gallons consumed.

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* See also Paper on "Hydraulic Supply in Towns," by Mr. E. B. Ellington (Proceedings 1895, page 353).

Mr. Henry Chapman is Chairman, and Messrs. Ellington and Woodall are the Engineers of the Company.

Millbank Pumping Station.—This station started working in 1889, and was originally laid out for 600 horse-power. It has recently been greatly enlarged by the erection of an entirely new engine-room, &c., on the west side of Millbank Street. There are now seven vertical inverted compound triple three-cylinder condensing engines of 200 horse-power each. The two parts of the station are connected by a tunnel with lifts. The water is pumped from the river and wells by hydraulic pumps, and delivered into high-level tanks, from which it is passed after treatment with lime through filters to other tanks at a lower level. From these tanks the water is pumped into the street mains. There are two accumulators at this station. The boilers are fitted with Vicars' mechanical stokers.

Wapping Pumping Station.—This station is situated on the side of the Shadwell Basin of the London Docks, and contains six 200 I.H.P. triple-expansion engines. The general arrangement is similar to Millbank, except that the water is taken from the dock basin, and there is an underground reservoir of filtered water.

THE COLONIAL CONSIGNMENT AND DISTRIBUTING CO.'S FROZEN AUSTRALASIAN MEAT STORE, LAMBETH.

These premises, called "Nelson's Wharf," cover 3½ acres, and are situated on the south side of the River Thames between Blackfriars Bridge and Waterloo Bridge, in Commercial Road, Lambeth. They were constructed in 1891 for the purpose of forming a central depôt, whence the frozen meat supplies from the Colonies might be received and distributed throughout the United Kingdom, inclusive of London itself. They were erected for Messrs. Nelson Brothers (now the above-named company) by Messrs. John Mowlem and Co., contractors, to the designs of Messrs. Bramwell and Harris, of Westminster.

The buildings comprise general offices, living rooms for caretaker and for a foreman, club and mess rooms, &c., stable for nineteen horses on the first floor level, with harness, &c., rooms and van accommodation under; a large covered courtyard for railway and other vans loading from a distributing platform; a tidal dock for two barges, open to the River Thames, with covered courtyard alongside; cold store for 250,000 sheep; engine and boiler house; carpenters', fitters', and electricians' shops; eighteen defrosting rooms, &c., with a jetty 90 feet long by 22 feet wide, having an iron overhanging roof 56 feet wide, sheltering two barges, the site being practically opposite the Temple Pier. A special feature of the cold store part of the building is that it is practically a brick-box on a concrete foundation without any side openings, the two lower floors being below the ground line. The timber structure supporting the six floors is self-contained and independent of the brick walls, the insulation being formed of hard-wood sawdust 12 to 15 inches thick encased in the usual double thickness of match-boarding with tarred paper sandwiched between.

Cargoes of frozen beef and sheep are received in barges loaded from ships in the docks and in the river, and have to be raised to the sixth or "Receiving and Distributing Floor" by hydraulic cranes, and elevators termed "Sheep Syphons." The latter are endless chains having arms upon them across which the sheep are laid, and are driven by a 3-cylinder Brotherhood hydraulic engine, and deliver the sheep on to a receiving table on the distributing floor. The apparatus is adjustable to the position of the barge at any state of the tide and whilst at work. From the table the sheep are sorted on to trucks and conveyed by hydraulic jiggers with wire-rope suspended cages on to the various floor-levels of the cold rooms; from which they are again raised by similar means when required for distribution, the trucks being lowered to the courtyard-level van-loading platform by hydraulic direct-acting lifts. There are nineteen hydraulic elevating machines, made by Messrs. Waygood and Co., eight of which, together with a steam-driven sheep-elevator on the jetty, are capable of dealing with barge cargoes. It is therefore a comparatively easy matter to receive 10,000 or 12,000 sheep per day as an ordinary day's work; whilst as many as from 17,000 to 20,000 sheep in and out of stock have been handled in one day.

Two systems of refrigeration are installed; one, the De La Vergne direct-expansion of ammonia process, for which there are two machines, each of 80 horse-power with 12-inch by 24-inch double-acting compressors, and compound-condensing steam-cylinders, with about 12 miles of 2-inch expansion pipes in the cold rooms, made by Messrs. L. Sterne and Co., of Glasgow; the other system is a cold-air compression and expansion machine of about 300 horse-power, made by Messrs. Haslam and Co., of Derby, with air-distributing ducts formed in the concrete foundation of the building, but which is seldom used. The "defrosting" plant is the invention of Sir Montague Nelson, Chairman of the Company, and consists of a series of rooms fitted with ammonia expansion pipes, and steam-heating pipes, &c., the purpose of which is to thaw out, or "defrost" beef and mutton to the extent of 4,500 sheep and 2,000 quarters of beef per week, giving a daily output for market deliveries. This process is both natural and efficient.

Electricity for lighting the cold rooms, offices, and premises generally, is generated by two of Messrs. J. and H. Gwynne and Co.'s vertical compound engines, each coupled direct to a Paterson and Cooper low-speed dynamo. Hydraulic-power water is supplied for the lifting apparatus at a pressure of 750 lbs. on the square inch, by a Smith and Vale compound duplex steam-pump, having 6-inch water-rams, working on a 15 feet stroke, 12 inches diameter accumulator. The London Hydraulic Power Co.'s service water at the same pressure is laid on through meters to the ring-main water service-pipes as a stand-by, when the pump is shut down for repairs.

The three Lancashire steel boilers 7 feet 6 inches diameter by 30 feet long, of which two are in use at one time, made by Messrs. Galloway, and fitted with Vicars' mechanical stokers, supply steam at 140 lbs. pressure. Service pumps for condenser-water and boiler-feed water, a filter, heater, and general steam-condenser and air-pump, complete an installation running day and night throughout the year. This establishment is now dealing with frozen colonial sheep and lambs at the rate of about 1,500,000 a year, also many thousands of single joints, and about 100,000 quarters of beef from New Zealand and Australia.

MESSRS. DOULTON AND CO., LAMBETH POTTERIES.

The Lambeth Works of Messrs. Doulton and Co., originally established in 1815 at Vauxhall on a very small scale, were removed in 1826 to the site of the present Head Office in High Street. Messrs. Doulton and Watts' works remained for many years devoted to the manufacture of ordinary stoneware for household, chemical, and sanitary purposes. Towards the middle of the century, the growth of chemical and sanitary science led to a more extended application of stoneware, and the works were gradually enlarged to meet the increasing demands of trade. Especially was this the case with the important industry of stoneware-pipemaking. On the initiative of Mr. Henry Doulton, the first factory ever equipped with specially-designed machinery for the manufacture of drain-pipes was erected in 1846 at Lambeth, to be followed within a few years by additional works at St. Helen's, Rowley Regis, and Smethwick. Beginning thus with pipes, the use of pottery has extended to ware of all kinds for sanitary purposes, not only in stoneware, but also in the more highly finished earthenwares of Staffordshire. About 1855 garden vases and pedestals were being made at Lambeth, and were soon followed by the definite introduction of terra-cotta for architectural purposes, a new factory eventually being required to accommodate the necessary processes. Among the modelled enrichments for this building, erected about 1867, are some of the earliest essays of George Tinworth, an artist whose well-known talents have since been always associated with the Lambeth Pottery. The manufacture of architectural terra-cotta has long outgrown this first building, and is now, at Lambeth, located principally in the building on the Albert Embankment, whose tall chimney-shaft is such a conspicuous landmark. There are also extensive works for terra-cotta at Rowley Regis, near Dudley. Among other developments now carried on at Lambeth may be mentioned the manufacture of crucibles and fire-clay wares, fire-places, mantelpieces and stoves in glazed ware, filters of all kinds, stoneware conduits for electric mains, fitted sanitary goods, and metal work of all kinds for sanitary purposes. Additional works for the latter manufacture have within the last few years been established at Paisley and Paris.

It was not till 1867 that the first tentative attempts were made to connect art workmanship with the previously rougher productions of domestic use. In the Paris Exhibition of that year a few vases and jugs were shown, decorated in the simplest possible manner with bands of colour. At South Kensington in 1871, pottery having been included as one of the exhibition classes, a more definite step was taken, and some seventy pieces of salt-glazed decorated stoneware were exhibited. They met at once with great appreciation from critics and the public, and Mr. Henry Doulton was encouraged to proceed with the new industry. At the succeeding exhibitions of Vienna 1873, Philadelphia 1876, and Paris 1878, very varied displays were made, that at Paris being awarded the Grand Prix, an honour repeated at Paris in 1889. There have been numerous and gratifying awards of this kind at other International Exhibitions, but the honour to which Mr. Henry Doulton attached perhaps most value was the visit paid to the Lambeth Works in 1885 by H.R.H. the Prince of Wales to present the "Albert Medal" of the Society of Arts, "in recognition of the impulse given by him to the production of artistic pottery in this country." Mr. Henry Doulton was knighted in 1887. The firm is now a limited company, Mr. Henry Lewis Doulton being Chairman and Managing Director. The number of men employed is about 4,500.

CITY OF LONDON ELECTRIC LIGHTING CO., BANKSIDE, SOUTHWARK.

This station, situated on the south side of the river, is placed on a site having river frontage, and the buildings are massive and substantial. A lofty building has been erected on the wharf, and is connected to the main building on the other side of the road by a bridge placed at an elevation of 50 feet. A fleet of barges is employed to bring the coal alongside the wharf, and a complete equipment of hydraulic appliances is placed in the building capable of hoisting the coal and other materials to a capacious bunker and store room on the top of the building. On the ground floor of this building the pumping machinery is placed for drawing water from the Thames for condensing purposes. Centrifugal pumps are employed, two being driven by steam engines, and a smaller set are connected to electric motors. At the entrance to the works is placed a large circular water-strainer in the line of the condensing water pipes. The machine consists of a slowly rotating wheel, worked by electricity.

The engine room is 430 feet long by 45 feet wide, and has a gallery on each side. The offices are placed in the centre of the controlling gallery, having a view of the whole length of the room. They are fitted up with a complete telephone exchange, connecting all parts of the works and the numerous distributing centres in the city. There are thirty sets of engines and dynamos, the largest being capable of giving an output of 1,500 kilowatts, or about 2,500 indicated horse-power. Three travelling-cranes, driven by electric motors, are in use, capable of dealing with any weight up to 45 tons.

The gallery on the opposite side of the room is known as the steam gallery, and provides every convenience for manipulating the steam-valves to each engine, and also the large valves in the main steam-pipes. A feature of interest is the arrangement of the water service to feed the boilers, as the whole of the work is performed from the gallery, and is quite distinct from the work of the stokers.

The boiler-house adjoins the engine-room, and contains thirty-three large water-tube boilers all fed by automatic stokers, which receive the fuel by chutes from the coal store overhead. The coal store contains about 2,000 tons, all of which is transported from the wharf bunker by means of a long chain with broad links which push the coal along a trough. A similar conveyor removes the ashes and deposits them into a bucket elevator for enabling them to be deposited on the wharf for removal.

For lighting purposes the City is divided into two districts, one half of the station supplying one district and the other half feeding the remainder. The machinery is also controlled from two separate boards, but if necessary a machine from one portion could be connected on to the other side of the works.

The generating plant of the north side of the station consists of ten Thomson-Houston generators, driven by Willans and Robinson's engines, while that of the southern section consists of Brush (Mordey) alternators, driven by Brush vertical engines, and two Ferranti fly-wheel alternator sets. The steam-generating plant consists mostly of Babcock and Wilcox boilers of the "double deck" type. Each boiler has 4,400 square feet of heating surface, and is composed of twenty sections, each consisting of nineteen lap-welded wrought-iron tubes 3 inches diameter by 15 feet long. There are two steam and water drums, each 48 inches diameter by

21 feet long, made of steel plate ½-inch thick. These drums are surmounted by a cross drum 24 inches diameter by 8 feet long, provided with two steam nozzles 7 inches diameter. The boilers are arranged in batteries. Many boilers are fitted with Vicars' mechanical stokers, and others are worked with the Babcock chain grate stoker, forced draught being provided by means of a Sturtevant blower, and induced draught by large fans made by Messrs. Heenan and Froude. The waste gases are discharged into the main flue, at the end of which are fuel economisers. The main steam-pipes are of steel, 10 inches diameter, with electrically welded flanges.

The high-tension current is carried to the transformer sub-stations by lead-sheathed concentric paper insulated cables drawn into wrought-iron pipes, troughs, and conduits, and are carried across the river by two routes, some going over Southwark Bridge and others over London Bridge. The low-tension mains are on the three-wire system. There are twenty-three sub-stations, which are in most cases special brick chambers, built below the surface of the road, and having man-hole doors which are brought up flush with the pavement on the footway. The number of lamps supplied by this station at the end of 1899 were 430,000 of 8 candle-power, and 540 arc lamps for street lighting. Considerable extensions are in progress for the supply of continuous current; the engines have been supplied by the E. P. Allis Co. of the United States, and others are being made by Messrs. Musgrave of Bolton.

Mr. Frank Bailey is the engineer to the company, Mr. F. H. Jackson, being the assistant engineer, and Mr. D. Wilson the superintendent of the generating works.

GREAT EASTERN RAILWAY LOCOMOTIVE, CARRIAGE, AND WAGON WORKS, STRATFORD.

(*Plate* 68.)

Members visiting these works will start from the main offices, a large block of buildings facing the Loughton line. A telephone exchange has been erected here, establishing inter-communication with the principal foremen in the works. The erecting and fitting shop, 350 feet by 142 feet, and 50 feet high, contains four bays running lengthwise, and has accommodation for fifty engines at a time. It was in this shop that an engine was built in December 1891 in the world's record time of ten working hours. This engine was set to work on coal trains between Peterborough and London immediately on being turned out of the shop, and ran 36,234 miles before receiving its finishing coat of paint. Its mileage to 31st December 1899 was 233,091. Four wheels coupled bogie express engines of the type of No. 1900, the "Claud Hamilton" now on exhibition at Paris, are at the present moment in course of erection. The principal dimensions of these engines are as under:—cylinders, 19 inches by 26 inches; diameter of wheels, driving and trailing, 7 feet; bogie, 3 feet 9 inches; working pressure of boiler, 180 lbs. per square inch; heating surface of tubes 1,516·5 square feet, and of firebox 114·0 square feet. The weight of engine in working order is 50·425 tons, of tender 35·05 tons, the total weight being 85·475 tons. The capacity of tender for water is 2,800 gallons, for oil 720 gallons, and for coal 30 cwt. These engines are fired with liquid fuel, the burners being provided with an auxiliary fuel supply, enabling much larger quantities of oil to be burnt than formerly, without increasing the expenditure of steam. The air-inducing rings are also of modified form, whereby their efficiency in atomising and distributing the oil fuel is considerably augmented. The fuel in passing from the tank on the tender to the firebox is heated by means of the exhaust steam from the Westinghouse pump, or, at will, by live steam from the boiler. In the smoke-box there is a battery of tubes through which air entering by an opening under the smoke-box door is heated by the waste gases. This air is delivered to the furnace through the liquid-fuel injector at a temperature of 600° to 800° Fahr., or it may, if desired for use with solid fuel, be led direct to the ash-pan. The slide-valves are balanced by strips somewhat resembling Richardson's strips, but by a new arrangement perfectly steam-tight joints are secured between the strips and the valve, and between the strips themselves, no matter how unevenly the strips or valve may wear or expand by the heat, Plate 68. The engine can be reversed either by hand or by compressed air from the main brake reservoir. The motion being balanced, a small frictional clutch will lock it in any position. One end of the reversing cylinder is always open to the main brake reservoir, and by means of a balancing valve the other end is always kept automatically at a pressure of 30 lbs. less than in the main brake reservoir. Should anything go wrong with the air-locking arrangement, mechanical locking takes place automatically. The driver can use the air lever or hand-wheel at will, without putting anything in or out of gear; when reversing by air the hand-wheel remains stationary. Usually it is difficult with a power-reversing gear to operate it when the engine is not in steam; in these engines it can be operated with facility whether in steam or "dead." The tender is fitted with apparatus for picking up water on the way, the scoop being lowered and lifted by means of compressed air. As has been the practice on the Great Eastern Railway for years past, the tool boxes are fitted at the engine end of the tender, thus obviating the necessity of the enginemen going to the back of the tender when the engine is in motion. The same purpose is served by the automatic recording apparatus with which each of these engines have been fitted, so that the men on the foot-plate can see at any moment how much water there is in the tender. It will be remembered that much was made of these two points during the recent Royal Commission on accidents to railway servants. The engines are fitted with Macallan's variable blast pipe, double sight-feed lubricators, exhaust steam injector, and steam sanding apparatus.

There are in the erecting shop four overhead cranes to lift 30 tons each, driven by ropes running at a velocity of 2,200 feet per minute, and twelve portable machines for cutting off tube ends, facing down safety-valve seatings, boring and facing cylinders, steam-chests and slide-valve faces; the latter operations being performed without removing the cylinders from the frames. Flexible shafts and portable pneumatic tools (the latter worked by compressed air at 80 lbs. per square inch pressure) are in constant use. The side bays are given up to heavy machinery. Over the bays on one side are the chemical laboratory (where analyses of metals, fuels, water, paints, oils, textures, &c., are constantly in progress), the supplementary drawing office (which is chiefly concerned with drawings of the works buildings, and machinery), and the pattern shop; whilst over the other side is the Westinghouse brake shop, in which there are sections of the Westinghouse pump, triple valve, and driver's valve, explaining the action of the Westinghouse brake. The machinery in the erecting shop, in common with that in all the other principal shops in the works, is driven by a double cylinder vertical engine, steam for which is obtained from a locomotive type boiler.

Round the erecting shop are grouped the various shops which supply it with the details required by the erectors. The smithy and steam-hammer shop contain gas furnaces, steam hammers, saws and other machinery, including a shearing machine capable of cutting iron four inches thick at one operation. The machine shop, a building 132 feet by 136 feet, contains 177 machines of various descriptions, grouped according to the class of work they turn out. The machines for turning out finished stud-bolts from the rough bar are good samples of modern automatic machinery. Other items of interest are the Medart straightening machine, the profiling and milling machines, the vertical turning and boring machines, and hexagon turret lathe.

The iron foundry, which covers 15,520 square feet, contains three cupolas, one of which is capable of melting 7 tons per hour; the other two each melt 3 tons per hour. Most of the moulding is done by hand, but castings which are required in large quantities, such as brake blocks, axle-boxes, &c., are moulded by means of machines. The shop is fitted with a 15-ton and a 10-ton travelling crane and eight jib cranes, ranging from 10 cwts. to 2½ tons. There are three core ovens, one 24 feet by 18 feet being used chiefly for cylinder work. The average turn out is 55 tons of castings per week.

The brass foundry, brass stores, and coppersmiths' shop, with the brass-finishing shop above, are grouped in one building. The brass-foundry has nine ordinary furnaces, from each of which eight charges per day may be taken. Plate patterns are largely used in this shop, which contains a Tabor pneumatic moulding machine, worked by a small air-compressor in an adjoining building, which contains also the hydraulic installation which supplies the whole of the power required in the different hydraulic presses, riveters, lifts, cranes, &c., in the works. The coppersmiths' and brass-finishing shops both contain some interesting machinery, including two pneumatic hammers, hydraulic testing-machine, seventeen lathes (nine screw-cutting), hydraulic pipe-bending machine, milling machine, and a group of machines for making copper and Stone's patent bronze flexible stays. The stays are cut from bars by a circular saw, then straightened by rollers and centered by a pneumatic hammer, and afterwards screwed the entire length. The slots in the bronze flexible stays are cut by means of a circular saw. In the brass-finishing shop are two automatic chasing saddle lathes. Special attention has been paid to the ventilation of the brass-foundry and coppersmiths' shop, large "Blackman" fans, 4 feet in diameter, being fixed in the walls and working with very satisfactory results.

The boiler shop, measuring 212 feet by 139 feet, contains six bays and a side wing of 77 feet by 46 feet. Pneumatic hammers and caulking tools are largely used in this shop. In the flanging shop adjoining there is a hydraulic flanging-press worked at a pressure of 1,680 lbs. per square inch. It has four 6-inch diameter rams for holding the work, and one 20-inch diameter ram which forces up the die with a maximum pressure of 236 tons. Adjoining the smithy and steam-hammer shop is the test house, which contains a 50-ton and a 75-ton testing machine, the latter of which is capable of testing chains up to 90 feet in length.

Near the main offices is the drawing office, close to which is the engine-repairing shop and its machine shop. The wheel shop contains some of the heaviest machinery in the works. It is 190 feet by 70 feet, and is built in two bays, each of which has a 6-ton overhead travelling-crane. There are sixteen wheel lathes and nine lathes for axles, crank-pins, &c. Crank-axles are turned and then machined round the webs for hooping in a slotting machine. After the hoops are shrunk on, the key-ways are cut in a duplex milling machine, and the cast-steel wheels are forced on to the axles by hydraulic pressure of from 80 to 120 tons. Every crank-axle is carefully examined with a view to the detection of flaws, and is condemned if the slightest flaw or pin-hole is found.

In the carriage department the whole of the passenger-train vehicles are built and repaired. There are extensive saw mills. In the body shop may be seen some of the new wide carriages in course of construction. These vehicles seat two more passengers per compartment than the ordinary carriages and have been designed by the locomotive superintendent to meet the constantly increasing traffic in suburban districts, the length and number of trains having practically reached their limit. There are two shops, the sewing machine and polishing shops, where female labour only is employed.

On the opposite side of the line are the oil-gas works, a carriage-wheel shop, a repairing shop, &c., and also the engine sheds and buildings connected with the running department. A special feature of the latter is the enginemen's dormitory, which contains sleeping accommodation for fifty men, each bed being in a separate cubicle. There is a reading and smoking-room, dining-room, kitchen and baths. It is lighted throughout by electricity, and is worked without "rules and regulations." It may be mentioned that the number of bed occupants from the opening of the building in November 1890 to the present date is over 150,000, and that it has twice been found necessary to enlarge the accommodation.

The wagon shops, which were originally built on the site now occupied by the carriage repairing shops, have been removed to Temple Mills, about a mile and a half distant. The question of wagon brakes is of special interest just now in connection with the recent Royal Commission on Railway Accidents. Various forms of "double" brakes fitted to Great Eastern wagons can be seen at Stratford, as also a special arrangement for balancing the doors of wagons.

Liquid fuel apparatus can be seen in use in the Stratford works on stationary boilers, rivet forges, and on locomotives. The fuel distributing station, which is most complete, is close by the running sheds. The oil fuel on arrival is emptied from the tank cars into a series of underground storage tanks with a total capacity of 50,000 gallons. From these it is pumped by a rotary pump through 3-inch mains to high-level cylindrical reservoirs, holding 40,000 gallons. The engine tanks are filled from the crane arms through 4-inch pipes, the flow being controlled by sluice valves at the extreme ends of the arms.

The Locomotive Superintendent is Mr. James Holden, M. I. Mech. E. The number of workpeople employed at Stratford and Temple Mills, including engine-drivers and firemen, is 6,700.

EAST LONDON WATER WORKS, LEE BRIDGE.

(*Plate* 69.)

The Lee Bridge Pumping Station has been largely extended, especially in pumping plant and machinery, since the abandonment of the pumping station at Old Ford. The engines are:—the "Victoria," erected in 1854, diameter of cylinder 100 inches and 11 feet stroke, diameter of pump 50 inches; the "Prince," diameter of cylinder 84 inches and 11 feet stroke, diameter of pump 45 inches; the "Princess" is an exact duplicate of the "Prince"; the "Duke" is a compound rotary engine, diameter of high-pressure cylinder is 23 inches, of low-pressure cylinder 39 inches, the strokes being respectively 4 feet 5 inches and 6 feet 6 inches; the pumps are of the bucket and plunger type, the bucket diameter being 27 inches; the "Duchess" is exactly similar to the "Duke." The "Horizontal" is a compound engine, with cylinders of 23 inches and 40 inches diameter, and stroke 3 feet; the diameter of pump is 22 inches. At the "Duke" and "Duchess" a new well has been sunk into the chalk. Exceptional difficulties were encountered in sinking the cylinders. From the surface of the ground to the chalk was entirely quicksand. Tunnels have been driven in the chalk to a great distance and in various directions. The water is raised by a compound direct-acting horizontal engine. Of the "Triples," the north, central, and south are triple-expansion engines of the inverted marine type, and were built to supply the place of the Cornish engines formerly at Old Ford. They are capable of forcing 42 million gallons daily into the company's district. The "Prince Consort" is a triple-expansion engine, capable of forcing 14 million gallons into the district. An additional well has been sunk into the chalk just adjoining this engine-house, and a triple-expansion direct-acting pumping-engine has been erected there. A new "Worthington" engine with Babcock and Wilcox boilers has been erected upon a site immediately adjoining the "Duke" and "Duchess" engines. There are also several turbines for pumping water, which are actuated by the fall of the River Lee.

At these works the main portion of the company's filtering operations are carried on. The filter beds are twenty-five in number, covering about 25 acres. The water is conveyed from the impounding reservoirs at Walthamstow by an open channel about a mile and a quarter long. A line of railway is connected from one end of the works to the other and to the Great Eastern Railway; and wharfage is also provided on the banks of the River Lee. There is also conveying machinery for taking coal out of barges and delivering it, without being handled, into the stores attached to the boiler houses. In addition steam cranes and grabs are in use. The whole of the works are lighted by electricity. The offices of the Engineer, Mr. W. B. Bryan, M. I. Mech. E., superintendents, and staff are at Lee Bridge.

Walthamstow.—The most important works at Walthamstow are the ten storage reservoirs, having a total area of 319 acres, and a total capacity of 1,200 million gallons. Two more, the "Banbury" and "Lockwood" reservoirs, are in course of construction, which will, when complete, bring up the above figures to nearly 480 acres, and 2,400 million gallons respectively.

The principal outlet from these reservoirs is through a 48-inches "Venturi" meter, which discharges the water into an open canal, through which it flows to the filter beds at Lee Bridge. This meter will register up to 60 million gallons a day. The reservoirs are filled through open cuts and culverts, which tap the River Lee about four miles above Walthamstow. At Walthamstow there is a well sunk into the chalk, the water from which is pumped by a horizontal compound engine and by a horizontal triple-expansion engine. Another well is also approaching completion, from which the water will be lifted by a horizontal triple-expansion engine. The adits at the bottom of these wells will ultimately be connected. The water from both of these wells can either be pumped into the open canal which feeds the Lee Bridge filters, or to the pump wells of a vertical triple-expansion engine (similar to the "Prince Consort" at Lee Bridge) which forces it direct into the district. There is also at Walthamstow a small set of filter beds.

In addition to the Lee Bridge and Walthamstow pumping stations, the company have works at Chingford, Ponder's End, Rammey Marsh, Waltham Abbey, Woodford, East Ham, Sunbury-on-Thames, and Hanworth Road, Sunbury. The high-level covered service reservoirs are situated at High Beech, Buckhurst Hill, Woodford, and Finsbury Park. The whole system provides water for 1,370,000 persons at 35 gallons per head per day.

MESSRS. JOHN I. THORNYCROFT AND CO., ENGINEERS AND SHIPBUILDERS, CHISWICK.

The works of this firm are situated on the River Thames at Chiswick (the nearest railway station on the District Railway is Turnham Green, and Chiswick on the London and South Western Railway).

Mr. Thornycroft built the first of his high-speed steam launches at Chiswick in 1864. The employment of these launches as torpedo craft became general ten years later, and the firm has since been constantly employed constructing torpedo boats, and more recently torpedo-boat destroyers, for nearly every country possessing such craft; the total number built, including those now under construction, amounts to 352 vessels. The firm have now in hand H.M. 30-knot torpedo-boat destroyer "Stag," and four first-class torpedo boats for

H.M. Government. These are of quite a new type, carrying a greater load and running considerably faster than any similar vessels possessed by our own or foreign navies; also for the French Government two twin-screw shallow-draught gun-boats, which will be sent out in floatable sections to be put together in China.

The mode of bending the tubes for the Thornycroft water-tube boiler, of which there are some 800,000 I.H.P. at work, will be found of interest; a new method of expanding tubes, invented by Dr. Burton, is also being experimented with.

The works cover six acres of ground and have a fifth of a mile river frontage, and are capable of employing 2,000 men. The ship-yard is entirely roofed over, which tends to produce good work and gives every facility for rapid construction.

THE MULTI-COLOUR PRINTING CO., LONDON.

At the printing office of this company, 24 Rosebery Avenue, was exhibited a four-colour printing machine of remarkable exactness, the paper being seized by a travelling alternating gripper and never released until all the colours had been impressed thereon. By a positive action, this gripper held the paper so firmly that it could not change its position, and, even though the sheet was not properly placed to the marks, the colours were in register with each other. The incorrectness of register in two-revolution and in stop-cylinder machines was thus avoided. The forme-rollers for each colour were quite independent of all others or combined in action with them as the case required. Each impression was under complete control, individually or all working together. With these advantages the machine-minder could deliver a sheet with a single colour, followed by one of two or more colours as he desired. The completion of the sheet in several colours at one operation enabled the operator to analyse his subject as a whole, and regulate the flow of ink accordingly.

STAINES RESERVOIRS WORKS.

(*Plate* 70.)

These works, which are the joint property of the New River, West Middlesex, and Grand Junction Water Companies, are near Staines. The intake from the Thames is situated in Buckinghamshire on the left bank of the river, about 300 yards above Bell Weir. At this point sluices and a sluicehouse are constructed, the intake being protected by screens to prevent leaves and other floating matter from entering the conduit. The first length of the conduit, for about 350 yards, is covered, as required by the Act of Parliament, and, running from the intake in a north-easterly direction, is carried in two steel syphons under the Colnebrook, after passing which it becomes an open conduit, the sides and bottom being formed of Portland cement concrete made in the proportion of about 4½ to 1. The conduit passes under the Great Western and London and South Western Railways in double tunnel and under the Wyrardisbury River through steel syphons, crosses Staines Moor, is syphoned under the River Colne, and runs to the pumping station, situated near the Billet Bridge which carries the London Road over the River Ash.

The pumping machinery will consist of five triple-expansion surface-condensing Worthington pumping-engines (one being a spare engine), each capable of delivering 16 million gallons of water daily into the reservoirs. Steam will be provided by six Babcock and Wilcox boilers (one spare), the working pressure being 150 lbs. per square inch. The water will be delivered into the reservoirs through two riveted steel mains, each 6 feet 4 inches diameter, joining into a steel pipe 7 feet 10½ inches internal diameter near the reservoir, from which branch pipes of the same diameter will be taken down through tunnels constructed in the clay, and connected to a water-tower near the corner of each reservoir, where the western and central embankments join. The tunnels and water towers are massive constructions of Portland cement concrete, the former lined, and the latter faced with blue bricks.

The stand-pipes for discharging water from the reservoirs will be of cast-iron, 5 feet internal diameter, having 48 inches and 36 inches sluice valves, with bell-mouth bends fitted to them, to enable the water to be drawn off at any desired level. These valves will be worked from a platform at the top of each of the water-towers, the gearing being enclosed in a suitable building. From the bottom of the stand-pipe of each reservoir a cast-iron pipe 4 feet diameter will convey the water through the tunnel and across the New Stanwell Road to a basin 50 feet diameter, in which a weir will be constructed for the purpose of aeration, and over which the water will be delivered into the conduit, which will rejoin the main conduit a little to the east of the pumping-station. Proper sluices will be provided for regulating the supply into and from the reservoirs.

The reservoirs Nos. 1 and 1A are about 1¼ miles long by five-eighths of a mile wide at their northern end, and nearly a mile wide at their southern end. The embankments vary in height from 21 feet to 39 feet, and are formed of material excavated from the interior of the reservoirs, the excavation just balancing the banks to prevent the expense of running material to spoil. The slopes of the embankments are three to one inside, and two to one outside the reservoirs. In the centre of each bank a puddle wall is constructed 6 feet thick at the top, 7 feet at the ground level, and tapering down to 4 feet, where it joins the London clay into which it is securely toothed. This construction, for which this part of the Thames Valley is favourably adapted, will make the reservoirs perfectly water-tight. The inside slopes of the reservoirs are lined with concrete 5 inches thick for a vertical depth of 15 feet, so as to resist any wave action which may take place in so large a sheet of water. The average depth of the water in the reservoirs is about 30 feet, and their content is 3,300 million gallons. The aqueduct and reservoirs will be guarded on all sides by unclimbable wrought-iron fencing, and the embankments will be sown with grass.

After leaving the pumping station, the conduit is reduced in section, and runs through the Billet Bridge by the side of Shortwood Common, under the London and South Western Railway, and across the fields, passes under the Staines and Kingston Road, the line of which it generally follows until it arrives at Sunbury Cross. From this point the aqueduct runs in a north-easterly direction, along the north side of the East London Waterworks at Hanworth, after which it bends to the south, passes under the Thames Valley branch of the London and South Western Railway, and is finally joined to a reservoir of about 30 million gallons capacity, which is constructed to the east of Kempton Park. The New River Company will take its water from the aqueduct between the East London Water Works and the Thames Valley Line. The West Middlesex and Grand Junction Companies will receive their proportion of the water from the Kempton Park reservoir just alluded to. Proper measuring apparatus of special construction will be provided on the aqueduct leading from the Thames to the pumping station, on the smaller aqueduct from Billet Bridge to Hampton, and at the outlet to each of the companies. Venturi meters will be fitted in the 7 feet 10½ inches pumping mains leading to the reservoir and in the 48-inch mains leading from the reservoir. Automatic records of the water passing down the aqueducts, of the level of the water in the aqueducts, and of the water passing through the several Venturi and other gauges, will be kept, and in most cases will be repeated in the engine-house. The capital provided under the Staines Reservoirs Acts, 1896 and 1898, is £1,250,000. The works have been designed, and are being carried out for the Joint Committee, by Messrs. Walter Hunter and Reginald E. Middleton, MM. I. Mech. E., of Westminster, the contract being entrusted to Messrs. John Aird and Sons, of Lambeth. Messrs. James Simpson and Co., London, are constructing the pumping engines; Messrs. Thomas Piggott and Co., Birmingham, the steel pipes; and Mr. G. Kent the gauges.

MESSRS. WILLANS AND ROBINSON, VICTORIA ENGINE WORKS, RUGBY.

See Plate 71.

These Works are situated upon a piece of land of about 23 acres, lying upon the south side of the London and North-Western Railway, about half-a-mile to the north-west of Rugby Station. A siding from the railway runs into the erecting shop and the loading shed, and gives access for railway trucks to the foundry. The whole of the railways about the Works (which include lines of ordinary railway gauge; of 3-feet gauge; and of 18-inches gauge) are at the uniform level of 298 feet above Ordnance datum.

The entrance to the Works is by a private approach road, with entrance gates and lodge. The Works proper are entered by gates between the general offices and the testing department, the time office at these gates serving for both the works and the testing department. From the open space in question there is also access to the building yard and workshops, now under construction in the north-east corner of the property.

Although the mess room, where coffee, etc., can be obtained in the early morning, as well as breakfast and dinner, is on the company's premises, yet it is outside the time office, and therefore no question can arise as to loss of time in connection with it. The mess room is in the hands of a refreshment contractor, who, in return for the use of the room and its appliances, together with a small wage and other advantages, is bound to cook and serve, without charge, provisions which are brought in by the men themselves. The hall is able to seat about 240 men; the basement contains bath rooms and lavatories for the use of the workmen. A path round the back of the mess room gives access to a long shed for storing bicycles.

The general offices face the open space referred to. On the ground floor is a large drawing office, lighted by windows on three sides. On the opposite side of the entrance hall are the offices of the accountant. Upstairs are the board room, directors' rooms, and the secretary's and commercial offices. The building is partially warmed by hot-water pipes, and is lighted by electricity. Each department has separate communication with the Works by an entrance at the back of the building.

The Works Buildings.—On passing the time office, the general arrangement of the Works will be readily seen. A road, or rather a broad asphalted path with railway lines alongside it, runs across the entire site, nearly parallel with the railway, and the principal buildings front on to this road or path. The space between the buildings and the railway, a strip tapering from above 100 feet in width, is planted as a rough shrubbery and permanent open space. It contains the "lodges" or reservoirs for condensing water, supplied by rain water from the roofs (which, when the present building extensions are completed, will cover nearly five acres) and from a well. There are also a few small detached buildings, such as the weigh-house, and an oil-and-waste store, which latter for fire reasons is kept away from the other buildings.

The principal buildings stand side by side, separated by alleys, some of which are utilised for out-door storage, &c. All the buildings are constructed in bays running north and south, divided in some cases by brick piers and arches, but generally by lattice steel stanchions, which carry traveller-girders. At a higher level the stanchions carry cross-girders, running east and west. These support rolled steel gutters, and light principals, the latter carrying "weaving shed" roofs, the ridges and gutters of which run east and west. The light is from the north. The stanchions or piers are in all cases spaced at 20-feet centres, in their respective north and south lines. Hence all the buildings are covered by a practically uniform system of roofing of 20 feet span, with the principals and other parts interchangeable. The width of the north and south bays, or "traveller bays," is varied according to circumstances. The several buildings are incapable of extension sideways, but they can be readily extended backwards, that is, into the company's "hinterland" to the south, at present used as allotment gardens for the workmen. The machine shop has already been extended in this way.

Entering by the works' gate, between the general offices and the testing department, on the left are the pattern stores, a group of five chambers each about 50 feet by 20 feet, separated from each other by walls which rise through the roof, and lighted from the outside only. The front or north bay has a raised roof, forming a photographic printing room, with arc lights for use in dull weather. The design of this building differs entirely from that of the others. The pattern shop, at present 135 feet by 30 feet, though separated from it by a wall, forms one building with the packing and forwarding shop. The machine and erecting shops will form together (when alterations now in progress are carried out) a single building measuring 500 feet frontage by 240 feet deep—except as to bays 1 and 2, constituting the erecting shop, which will be 320 feet deep. The completed building will cover about 127,500 square feet, or nearly three acres. The erecting shop bays, Nos. 1 and 2, are each at present 40 feet wide; they will be extended southwards by 80 feet, and bay No. 1 will be widened in the new part to 60 feet, and will have a 25-ton traveller with about 12 feet higher lift than the travellers in the existing erecting bays. The erecting shop is distinct from the machine shop, though in the same building. Bays 3 and 4, each 22 feet wide, are for manufactured stores, that is, standard parts of engines waiting issue under erecting orders. No. 5 is a fitting bay, 22 feet wide, for putting together steam-gland boxes, connecting-rod brasses, and pistons and followers. Bays Nos. 6 to 10 are machine bays, each 22 feet wide. The heaviest of the new tools, for making very large engines, will be in the new back part of bays 13–16. The front of the building is at present devoted, on the ground level, to the tool room, to the works engine and boiler, and to various stores. On the gallery overhead are the offices of the works manager.

The foundry at present covers about 22,000 square feet, but will shortly be enlarged to 57,000 square feet. The various bays, including those in the testing department, are commanded by 38 electrical travelling cranes, varying from 3 to 25 tons, besides a certain number of hand-cranes.

The testing department lies outside the gates of the Works, but is connected, by a 3-foot gauge tramway, with the erecting shop, from which engines are brought for test after completion. The main building of the testing department, unlike the others, fronts to the south, and measures about 110 feet by 100 feet. It has five north and south bays (22-feet centres) commanded by electric travellers. The roof is of the weaving-shed pattern, as elsewhere, with northern light. A part of the building forms the boiler house, in which are four Niclausse boilers of 250 H.P. each, made by the company. Engines are tested here under steam before going away, and if required they can be tested for steam consumption per I.H.P., per E.H.P., or per B.H.P. One of Froude's water-brakes, made by Messrs. Mather and Platt, is available for testing engines up to 700 H.P. The east bay of the building is devoted to the lighting and power station, from which are run the electric cranes and various motors. An accumulator house, resistance house, coal store, &c., are in annexes to the north of the building. A new and larger power station is contemplated, but the old one will be retained for the testing department and for lighting the offices, &c.

Attention is directed to the system of jointed steam-pipes, to allow of the rapid coupling up of engines brought in for test; to the flexible connections for exhaust; the portable condensers and air-pumps which can be placed quickly in position beside each engine; to the system of tanks and weighing machines for weighing the condensed water from each engine under test, and the arrangements for recording the results; and to the standard instruments for testing and verifying the electrical measurements. Each engine after test is dismantled, partly to see if all is right, and partly to enable the records to be corrected in case the drawing-office instructions have been in any way departed from during construction. The engine is then re-erected, unless of large size, and returned to the packing shop for despatch.

The works at Thames Ditton are still, as regards the machine shop, fully employed upom smaller classes of standard work, including all sizes of trunks or hollow piston-rods. All the work done at Thames Ditton is forwarded to Rugby for inspection. No erecting is done at Thames Ditton.

The Willans Engine.—The principal product of the Works is the well-known Willans central-valve engine, of which, in June 1900, some 340,000 horse-power were installed, or were on order, for electric lighting, electric traction, and other purposes. The largest engines of the type then under construction were two, to indicate 2,400 H.P. each (3,000 as "emergency load") for the Glasgow Corporation, about 13,000 H.P. being already installed in the lighting stations of this corporation. A third engine of this size is shown in the Paris Exhibition, coupled to a Siemens continuous-current dynamo; the two constitute the most powerful steam-dynamo in the Exhibition. No less than twenty-six engines of 1,200 horse-power have been completed, or remain still under construction, since the beginning of 1899. Of other engines under construction there are eleven of 800 horse-power, eight of 700, sixteen of 550, ten of 450, and thirty-one of 360 horse-power, while the total horse-power at present in hand exceeds 80,000.

It may be of interest to add that the business was commenced at Thames Ditton in 1881, for the construction of small steam yachts and launches, and of small marine engines. The central valve-engine was a later development, and its great success led to the reconstruction of the firm in 1888 as a private company. By a later reconstruction in 1893 the present public company was constituted. Mr. Willans, the chairman of the first company, died in 1892, after having, by his experiments and investigations, conferred the greatest benefits upon the science of steam engineering, but without seeing the great results which were to flow from his brilliant invention.

THE THAMES IRON WORKS, SHIPBUILDING, AND ENGINEERING CO., BLACKWALL.

The following is a list of the principal objects of interest to be seen on the occasion of the visit of the members.

Civil Engineering Department.—Girder work for the Gold Coast (Tarkwa Railway); steel cement stock boxes and columns; spans of various sizes for the Norwegian Trunk Railways; 30-feet spans for the East Indian Railway; steel freezing cells for the Atlas Co. of Copenhagen; spans of various sizes for the Burma Railways; spans of various sizes for the Bengal-Nagpur Railway, and roofing and steel constructional work of various descriptions.

Tools.—Drilling and milling machines driven by electric power; planing, punching and shearing machines; fitting and turning shops; cold saws; angle-straightening machine; electric traveller; riveting by hydraulic power; hydraulic press, and other tools.

Shipbuilding Department.—H.M.S. "Duncan" and H.M.S. "Cornwallis," first-class armoured battleships, in course of construction for H.M. Navy, of the following dimensions:—Length 405 feet, breadth 75 feet 6 inches, draught of water 26 feet 6 inches, displacement 14,000 tons, indicated horse-power 18,000, and speed of 20 knots. The machinery of 18,000 I.H.P. for these vessels, together with a similar set for H.M.S. "Albemarle," is being constructed at the company's engineering works at Greenwich, recently taken over from Messrs. John Penn and Sons. In the boat-building sheds are a number of life-boats for the Royal National Lifeboat Institution, with whom the company has a contract for the construction and repair of all their boats. Steel barges are also being constructed for Messrs. W. Cory and Son. There are also two dry docks.

Shops and Tools.—Large rolls in forge, engineers' shops, hydraulic bending or flanging machine, ship-fitters' shop, blacksmiths' shop, light platers' shop, boat shed and lifeboats, saw mills and large 42-inch saw frame, hydraulic band-saw frame, brass finishers' shop, brass foundry, bending slabs, pneumatic tools and caulkers, electric drills, and other modern labour-saving tools.

Electrical Engineering Department.—This department undertakes contracts for electric light and power installations, and carries out the electrical equipment of the ships built by the company and general electrical work. Dynamos, motors, electric fans, portable electrical drilling machines, searchlight projectors, switches, switchboards, &c., are manufactured in the machine shops facing the river. In conjunction with the transference of the marine engineering department to the newly-acquired works at Greenwich, the present machine shops will be devoted almost entirely to electrical manufactures, and the resources of this department will be greatly augmented. The contracts at present in hand include dynamos and electric installations for the Poplar Union, the Borough of West Ham, Barking Electric Tramways, electric pumps for the Central London Railway, &c. A central generating station has been established in the works for supplying current for consumption in the several departments. The installation consists of three locomotive and two gunboat boilers, the latter of the company's manufacture, aggregating 600 I.H.P. There are nine sets of engines and dynamos aggregating 350 kilowatts, three sets being built by the Thames Iron Works. Distribution of current is effected on the three-wire system, the main cables to the distributing centres being of vulcanised indiarubber insulation, laid in cast-iron pipes underground. The electric current generated is chiefly used for lighting purposes, but several motors are employed in the works for driving machinery, and the use of electricity for power purposes is in course of extension. Electro-galvanising of Belleville and other boiler tubes, steam pipes, &c., may be seen at the plant adjoining the boat-building sheds. This galvanising plant is the largest in the kingdom. Current for plating is obtained by transformation from the electric-lighting mains. Portable electric drilling machines are a speciality of the company, and examples of various kinds will be seen at the works.

Dry Dock Department.—This department comprises the shear legs capable of lifting 80 tons, and large and a small dry docks in which repairs are carried out for the P. and O. Steam Navigation Co., the Castle line, and all the principal lines sailing from the Thames.

THE RIVER THAMES, FROM LONDON BRIDGE TO THE NORE.

Old Swan Pier, situated just above London Bridge, is the point of departure for many pleasure steamers. Immediately behind is the Hall belonging to the Fishmongers' Company. Passing under London Bridge, which was opened by William IV in 1831, the steamer enters the "Pool," one of the most characteristic features of the lower Thames. It is divided into the upper and lower Pool, the point of division being the headquarters station of the Thames Police at Wapping. Three hundred yards beyond London Bridge on the left is Billingsgate Fish Market. A market has existed there for many centuries, and it was made a free and open market in 1699 by Act of William III. The present building was completed in 1877. Along the front runs a broad floating stage, alongside of which come the smaller craft by which the water-borne fish is brought up the river.

Near Billingsgate, on the north side of the river, is the Custom House, with a river front extending 488 feet. The present building, erected in 1825, is the fourth on the same site. The next object of interest is the Tower Bridge, which was built, at a cost of over a million and a quarter pounds, to relieve the congested traffic of London Bridge, and was opened by the Prince of Wales, in the name of the Queen, in 1894. It consists of three spans, the two side ones being on the suspension principle, while the middle span opens on the bascule principle. Above the bascule, 140 feet above high-water mark, is a permanent footway. The opening and shutting of the bridge, to admit of the passage of large vessels, is carried out by hydraulic motors. Above the bridge on the left is seen the Tower of London. For five centuries it was a residence of the Court, but ceased to be so on the accession of Elizabeth. The most ancient and complete portion is the quadrangular keep, called the White Tower, 90 feet in height, and one of the oldest portions is the Traitors' Gate, with its round towers at each angle, and the deep stone stairs that led from the water to the prison.

On the Surrey side of the river, after passing London Bridge, the church of St. Olave is seen; then comes Horsleydown, where the parish butts were set up for archery in the days of Henry VIII. Further on are the Commercial Docks, which occupy the trenches cut by Canute in the eleventh century.

On the left beyond the Tower are the St. Katherine's Docks. In order to construct these docks, the entire parish of St. Katherine, with its 1,250 houses, was excavated and carried away—the earth to raise the low ground about Belgrave Square, the college to be rebuilt in Regent's Park. Very near, and below, are the London Docks; and entering Limehouse Reach, the Surrey Commercial Docks are passed on the right, the West India and Millwall Docks being on the left. Deptford, on the right, is next seen. Here Peter the Great lived whilst studying and working at the dockyard. The present Trinity Brethren owe their origin to Henry VIII, who granted leave to the "shipmen and mariners of England" to found in the parish church at Deptford a guild or brotherhood of the Holy Trinity and St. Clement, with authority to make by-laws among themselves for the advantage and increase of shipping. Opposite Deptford is the Isle of Dogs, where Messrs. Yarrow's torpedo-boat and steam-launch works are situated.

Greenwich, now noted for its hospital, observatory, and park, is full of historic associations. Queen Elizabeth frequently resided there. James I commenced a building at Greenwich for Anne of Denmark, which Henrietta Maria employed Inigo Jones to finish. After the Restoration, Charles II began a new palace and formed the park; but only that part of the palace which now forms a portion of the west wing of the hospital was completed. William III ordered, as a tribute to Queen Mary's memory, plans for an additional building by Sir Christopher Wren, which was opened in 1705. In 1873 it was converted into a Royal Naval College. The observatory was erected in 1675. At Blackwall, on the left are the East India Docks, and further down the river are the Victoria and Albert Docks.

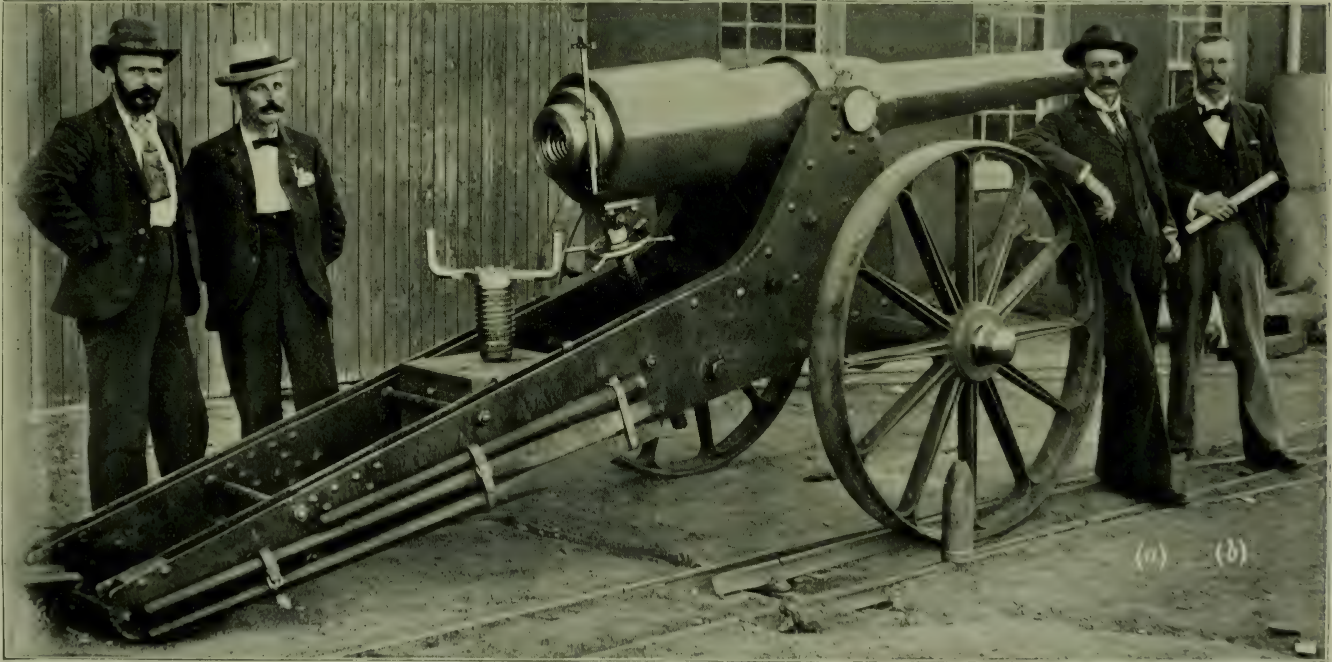
Woolwich Reach is two miles in length. On the north bank are the famous Woolwich Gardens, and on the south are the dockyard, arsenal, and the training-ship "Warspite." The dockyard was formerly used for the construction of ships for the Royal Navy, but was closed in 1869. Erith is a popular yachting station, and a favourite point for starting sailing matches. Passing Purfleet, the next point of interest is Ingress Abbey on the right, which was built from stones originally used in the construction of London Bridge. The training-ships "Exmouth" and "Shaftesbury" are moored off Grays. Rosherville, with its famous gardens, is seen just before reaching Gravesend. On the opposite shore is Tilbury, where Queen Elizabeth in 1588 reviewed her forces soon after the dispersion of the Spanish Armada. The Tilbury Docks were opened in 1886, at a cost of £3,000,000, and occupy a space of 100 acres, which can be extended if necessary, the Tidal Basin taking 19 acres. The entrance is 300 feet wide, and the depth at low tide is 26 feet, so that the largest ships can pass at all times. The largest of the four docks is 23 acres in extent. Opposite Tilbury is Gravesend, where all outward-bound ships are obliged to take on board pilots, and homeward-bound vessels receive the Custom House officers. The town, which has been incorporated as a municipal borough since the days of Elizabeth, belongs to the Chatham military district; here are the headquarters of the Nore and New Thames Yacht Clubs. The majority of the chief races of the London Yacht Clubs finish in Gravesend Reach.

Soon after leaving Gravesend, the river widens considerably. At London Bridge at high tide it is 290 yards across, at Blackwall it is 380 yards, at Gravesend 800, while ten miles lower at the London Stone—which marks the boundary of the jurisdiction of the City of London—it is nearly four and a half miles across. Passing coastguard stations, batteries, the Mucking and Chapman lights, Southend is reached. Its pier is one mile and a quarter in length, owing to the tide receding for nearly a mile. The structure has cost £100,000, and includes a hall for public performances, a reading-room, and other attractions. The pier is brilliantly illuminated with electric light, and electric cars run throughout its length.

Immediately below Southend is Shoeburyness, where the shore rapidly trends away. On the opposite side, by Sheerness, the River Medway unites with the Thames. Sheerness owes its fame to the battery—which guards the entrance to the Medway—and to its dockyard. Off Sheerness is the Nore Lightship. It is the first sea light to be passed after leaving the port of London, and is the first in seniority of its kind, for at this point the first lightship set afloat on the coast of England was stationed in 1731. The river is six miles wide here.

CONSTRUCTION OF "LONG CECIL" GUN.

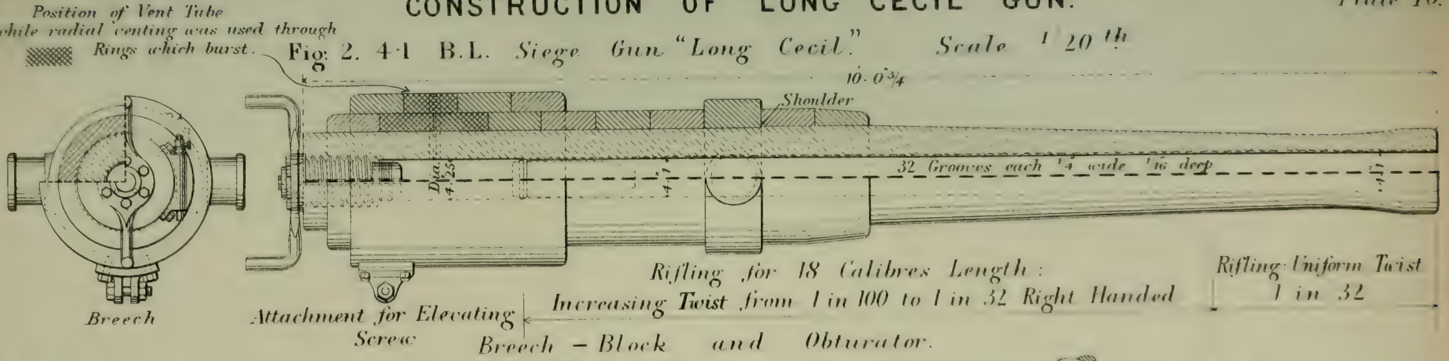
Fig. 1. *4·1 inch B.L. Siege Gun "Long Cecil" made at the workshops of the De Beers Consolidated Mines during the Siege of Kimberley, 1899-1900.*



(*a*) G. Labram, Late Chief Engineer D. B. C. M., killed 9th Feb., 1900. (*b*) E. Goffe, Chief Draughtsman, D. B. C. M.

CONSTRUCTION OF "LONG CECIL" GUN.

Fig: 2. 4·1 B.L. Siege Gun "Long Cecil." Scale 1/20th


Position of Vent Tube
while radial venting was used through
▩ Rings which burst.
10·0¾
Shoulder
Dia. 4·25
4·1
32 Grooves each ¼ wide 1/16 deep
4·1
Breech
Attachment for Elevating Screw
Breech - Block and Obturator.

Rifling for 18 Calibres Length: Increasing Twist from 1 in 100 to 1 in 32 Right Handed

Rifling: Uniform Twist 1 in 32

Fig: 3.

As First Made.

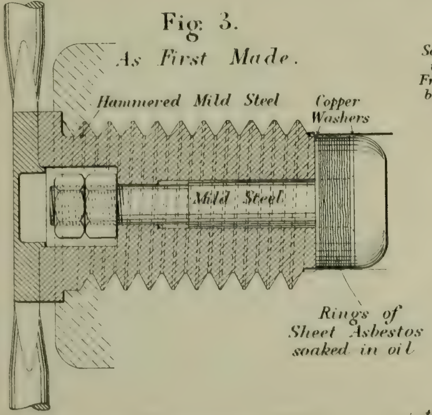
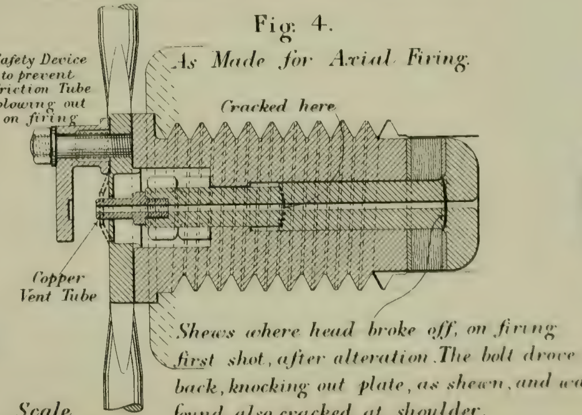


Fig: 4.

As Made for Axial Firing.

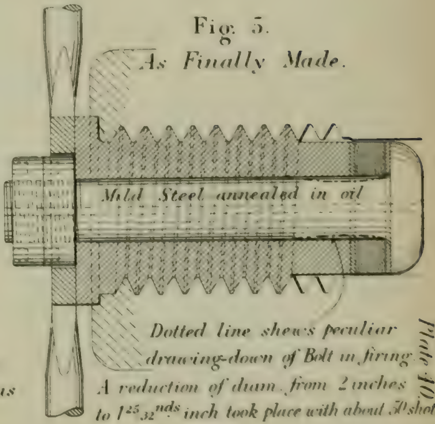

Safety Device to prevent Friction Tube blowing out on firing
Cracked here
Copper Vent Tube

Shews where head broke off, on firing first shot, after alteration. The bolt drove back, knocking out plate, as shewn, and was found also cracked at shoulder.

Scale 1/6th Full size

Fig: 5.

As Finally Made.



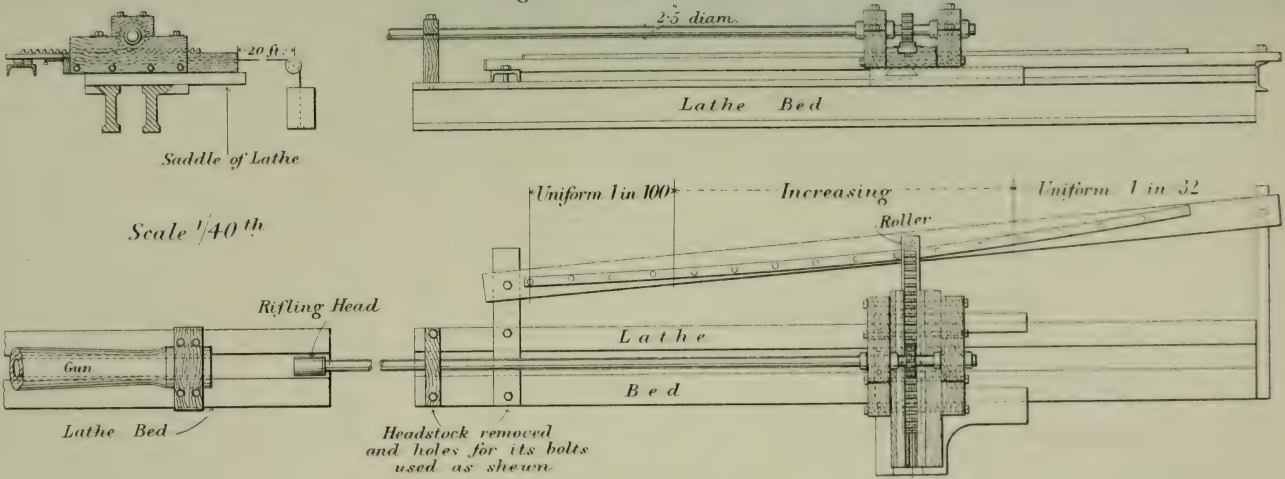
Dotted line shews peculiar drawing-down of Bolt in firing. A reduction of diam. from 2 inches to $1\frac{25}{32}$nds inch took place with about 50 shot.

Plate 40.

Mechanical Engineers 1900.

CONSTRUCTION OF "LONG CECIL" GUN.

Fig. 6. *Rifling Device.*



Boring and Rifling Tools.

Fig. 7. *Boring (Roughing).*

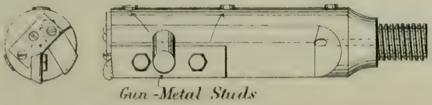


Fig. 8. *Boring (Finishing).*
Similar Tool also used for Powder Chamber.

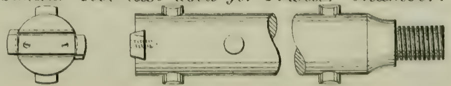


Fig. 9. *Rifling Head.*

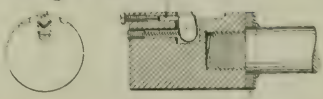
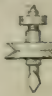


Fig. 10. *Drill.*



Scale 1/10th Full size

Mechanical Engineers 1900.

CONSTRUCTION OF "LONG CECIL" GUN.

Ring Shells made at the workshops of the D.B.C. *Mines during the Siege of Kimberley, 1899-1900.*

Fig. 11. *For* 4·1 *inch* B.L. *Siege Gun "Long Cecil."*

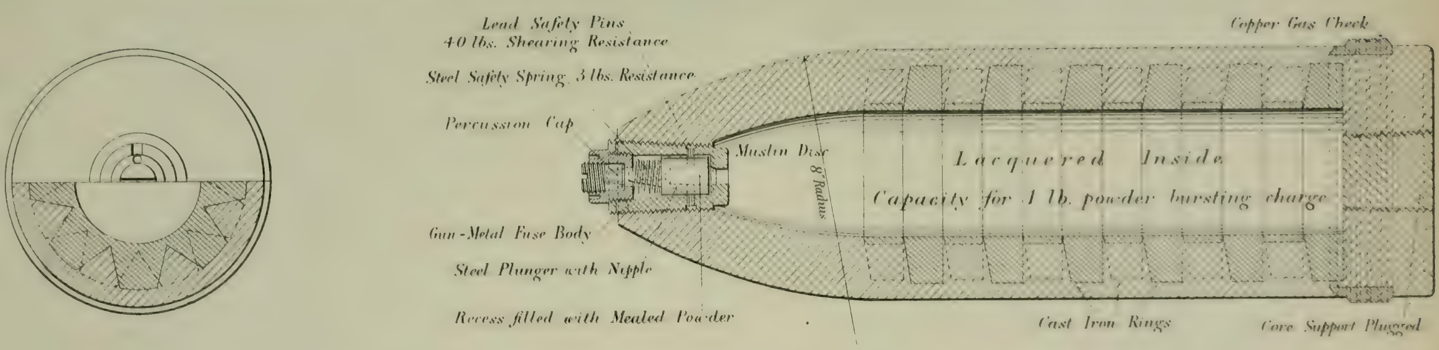
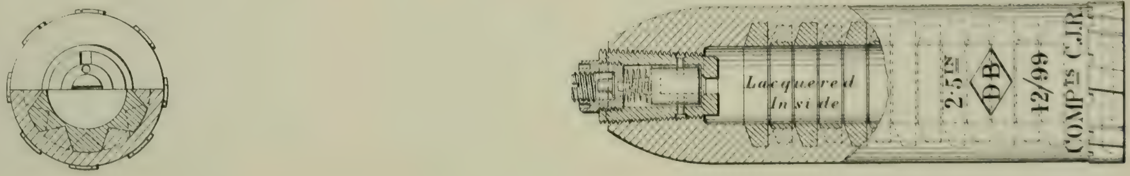

Lead Safety Pins
40 lbs. Shearing Resistance
Steel Safety Spring 3 lbs. Resistance
Percussion Cap
Gun-Metal Fuse Body
Steel Plunger with Nipple
Recess filled with Mealed Powder
Muslin Disc
8" Radius
Lacquered Inside
Capacity for 1 lb. powder bursting charge
Copper Gas Check
Cast Iron Rings
Core Support Plugged

Fig. 12. *For* 2·5 *inch* R.M.L. *Guns* R.A & D.F.A.



Scale 1/3 *full size*

Mechanical Engineers 1900.

FRENCH LOCOMOTIVE PRACTICE.

Fig. 1. *No.* 701, *Nord.*

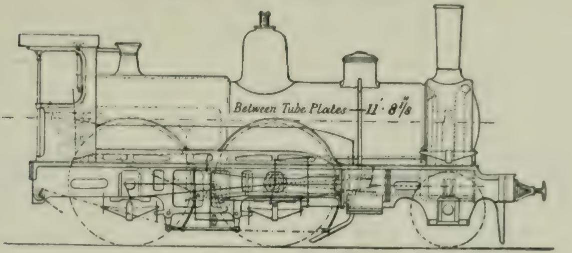


Fig. 2. *Nos.* 2161—2180, *Nord.*

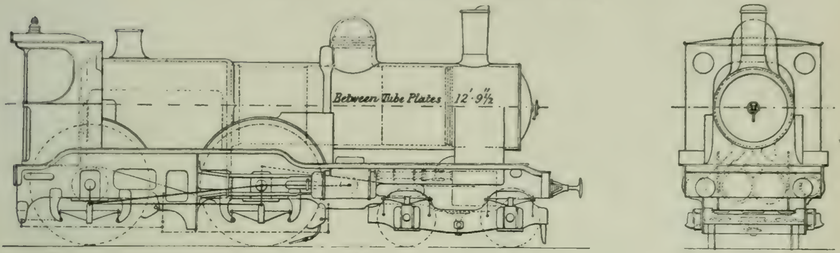


Fig. 3. *Nos.* 501 *and* 502, *Ouest.*

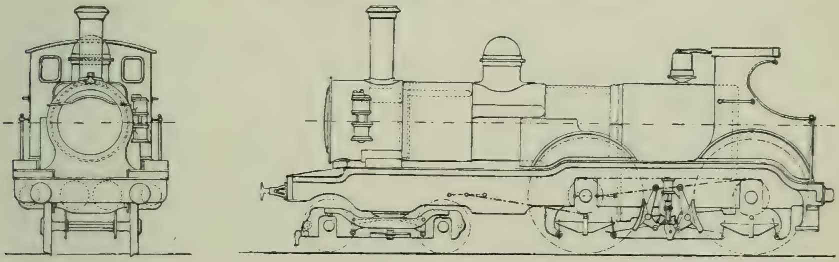
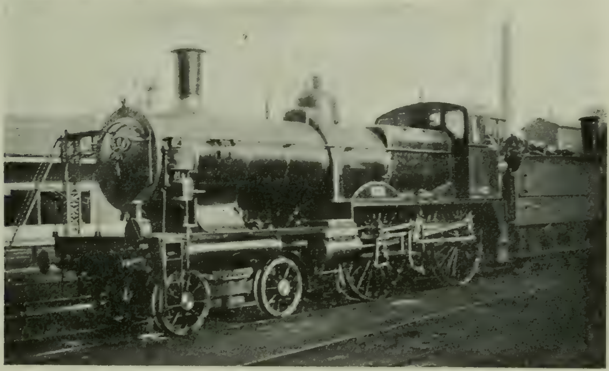
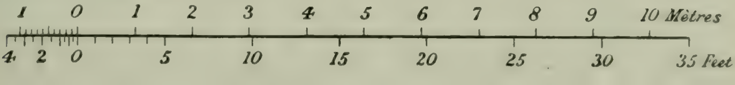


Fig. 4. *No.* 508, *Ouest.*



Mechanical Engineers 1900.


1 0 1 2 3 4 5 6 7 8 9 10 Mètres
4 2 0 5 10 15 20 25 30 35 Feet

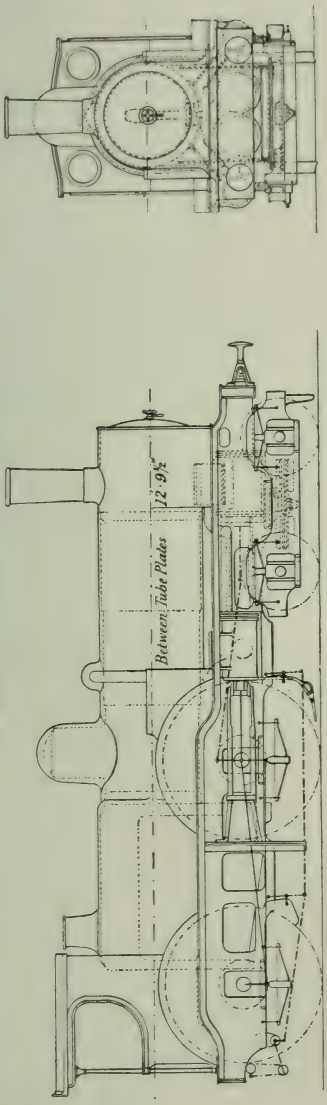


Fig. 5. *Nos.* 2138—2157, *Nord.*

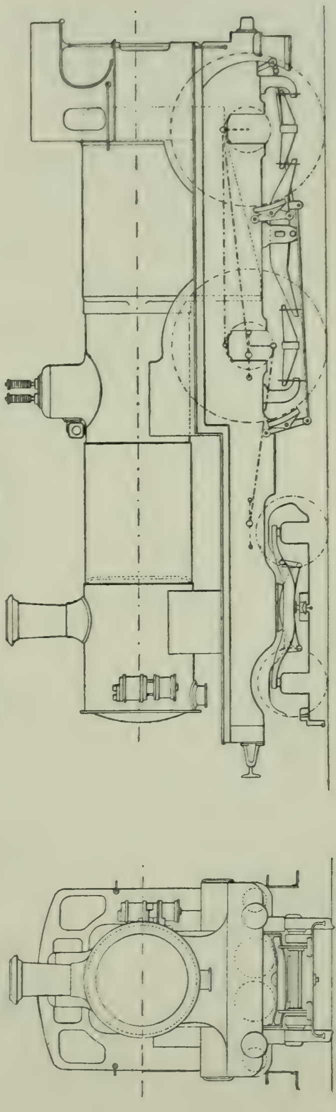
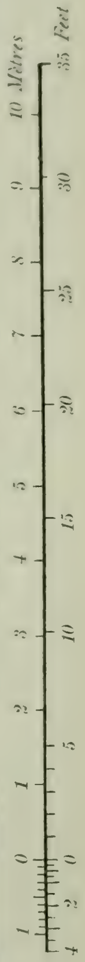


Fig. 6. *Nos.* 503—542, *Ouest.*



Mechanical Engineers 1900.

Fig. 7. *Nos.* 1701—1714, *Midi.*

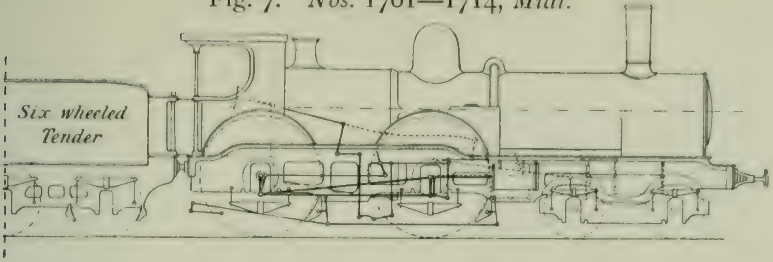


Fig. 8. *Nos.* 1751—1774, *Midi.*

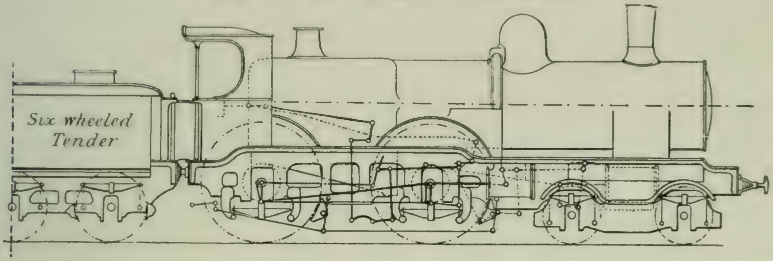


Fig. 9. *Nos.* C 61—150, *Paris-Lyons-Méditerranée.*

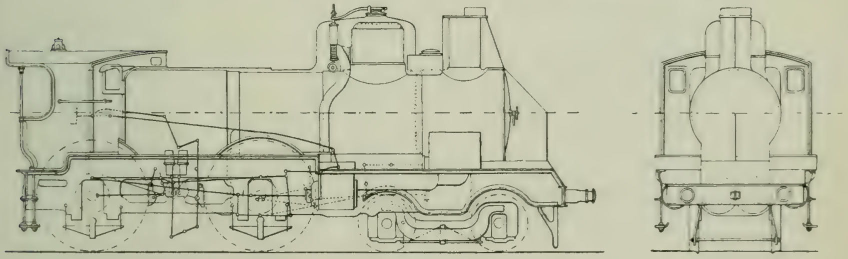
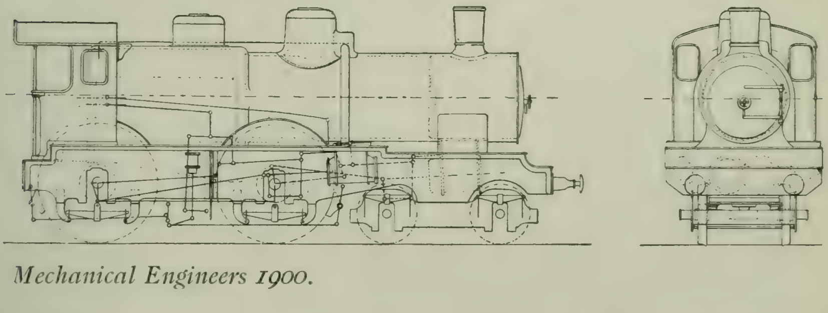
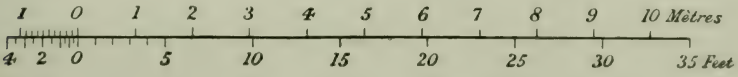


Fig. 10. *Nos.* 2401—2432, *Est.*





FRENCH LOCOMOTIVE PRACTICE.

Fig. 11. *Nos.* 2641 *and* 2642, *Nord.* *"Atlantic" type.*

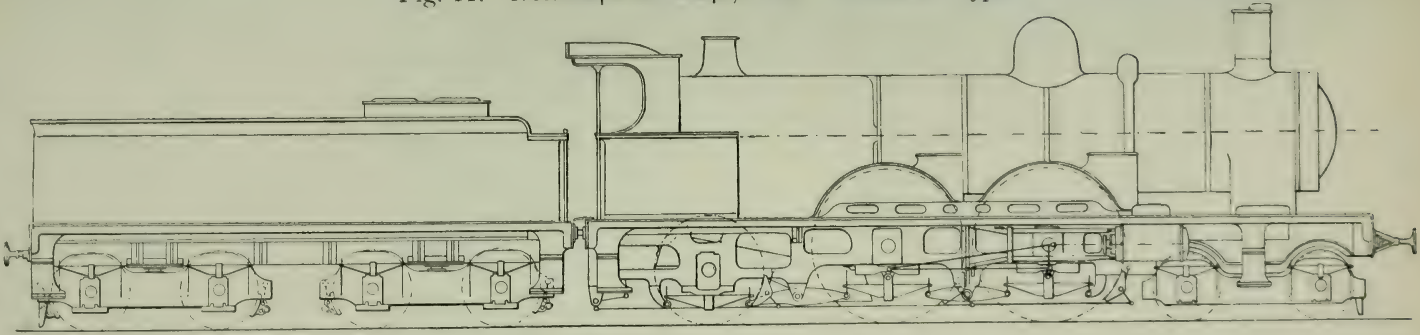
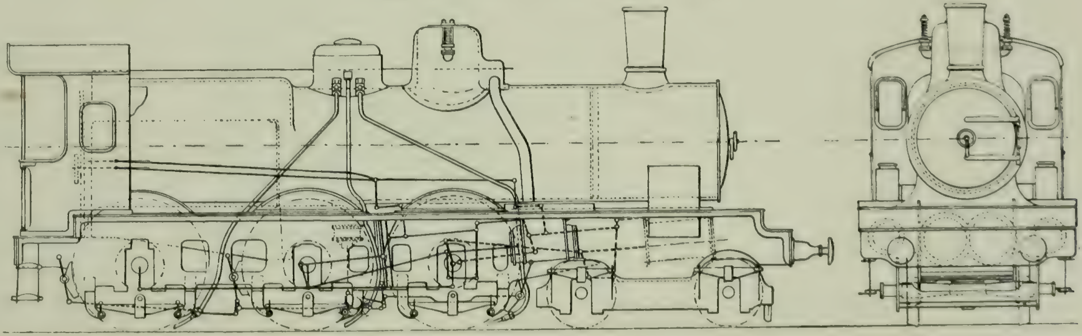


Fig. 12. *Nos.* 3401—3450, *Est.*



(Scale see Plate 44.)

Mechanical Engineers 1900.

Fig. 13. *Nos.* 3121—3170, *Nord.*

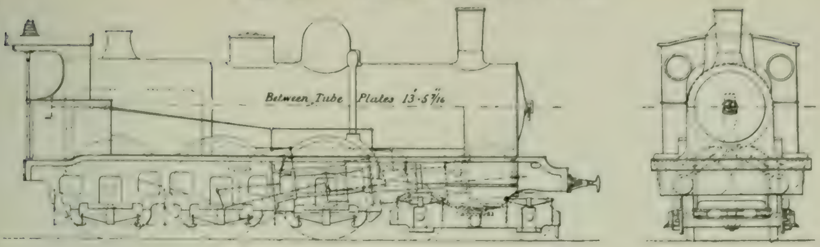


Fig. 14. *Nos.* 2501—2525, *Ouest.*

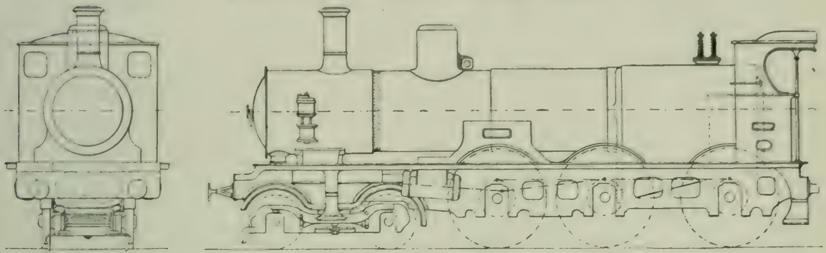


Fig. 15. *No.* 2504, *Ouest.*

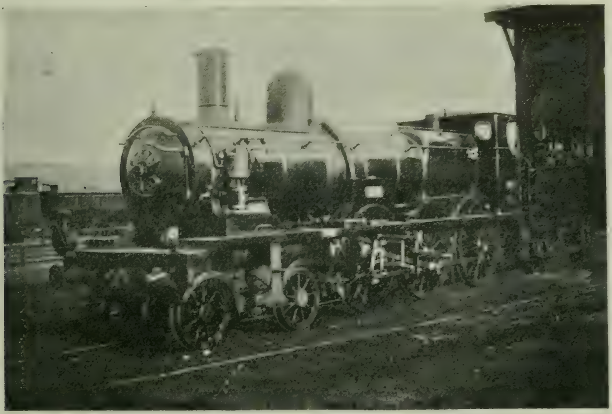
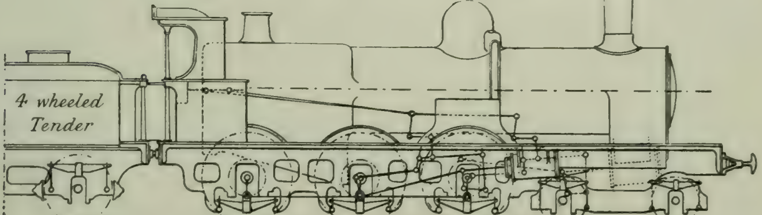


Fig. 16. *Nos.* 1402—1415, *Midi.*



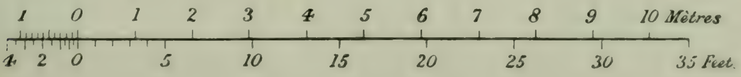

1 0 1 2 3 4 5 6 7 8 9 10 Mètres
4 2 0 5 10 15 20 25 30 35 Feet.

Fig. 17. *Nos.* 1303—1312, *Midi.*

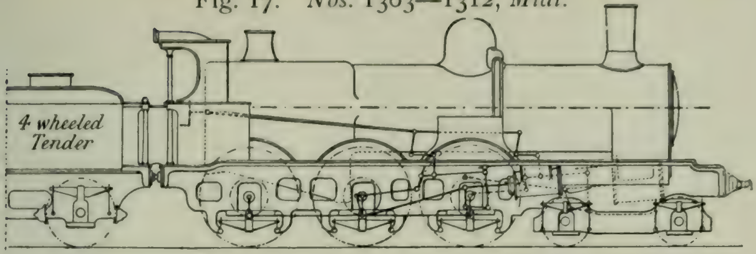


Fig. 18. *Nos.* 3401—3550, *Paris-Lyons-Méditerranée.*

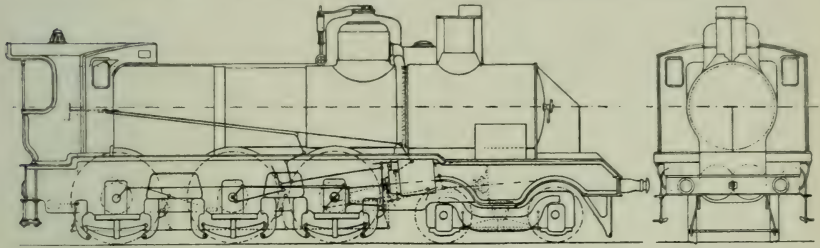


Fig. 19. *Nos.* 4521—4530, *Paris-Lyons-Méditerranée.*

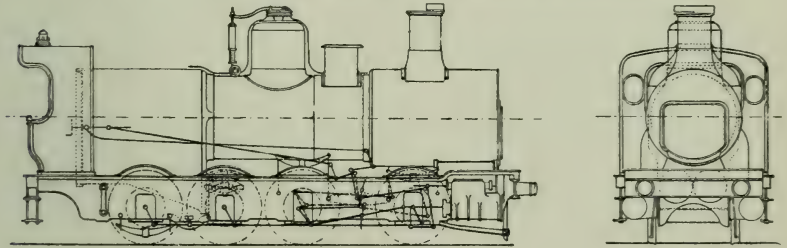
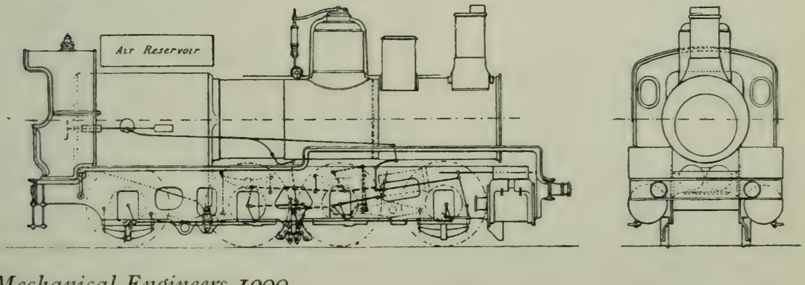
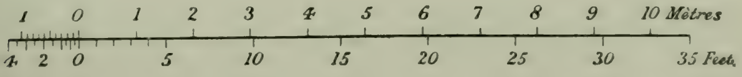


Fig. 20. *Nos.* 3211—3260, 3301—3362, *Paris-Lyons-Méditerranée.*



Mechanical Engineers 1900.


1 0 1 2 3 4 5 6 7 8 9 10 Mètres
4 2 0 5 10 15 20 25 30 35 Feet

FRENCH LOCOMOTIVE PRACTICE. *Plate 49.*

Reversing Gears for 4-Cyl. Compound Locomotive.

Fig. 21. *With parallel screws.*
Scale 1/8th.

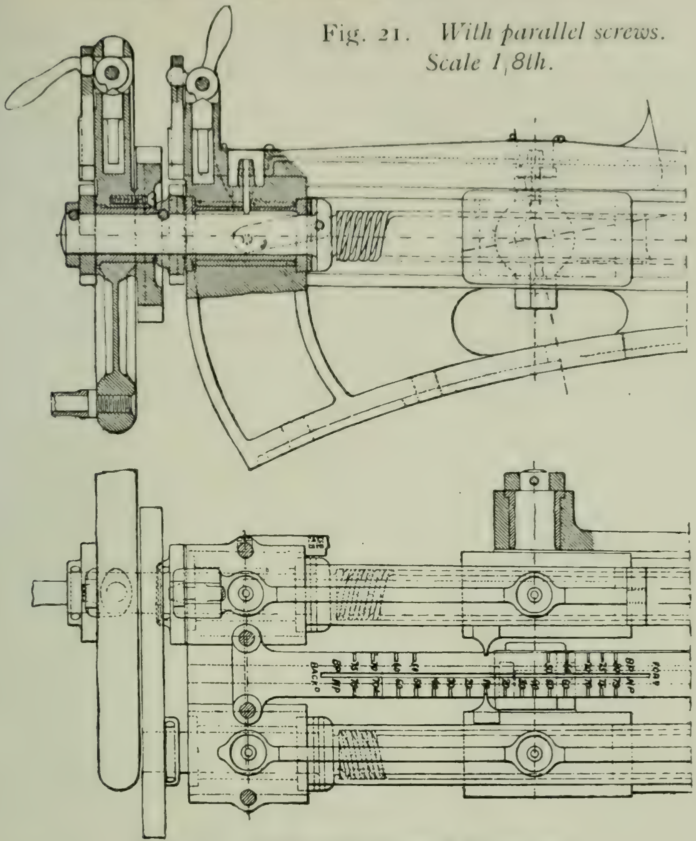
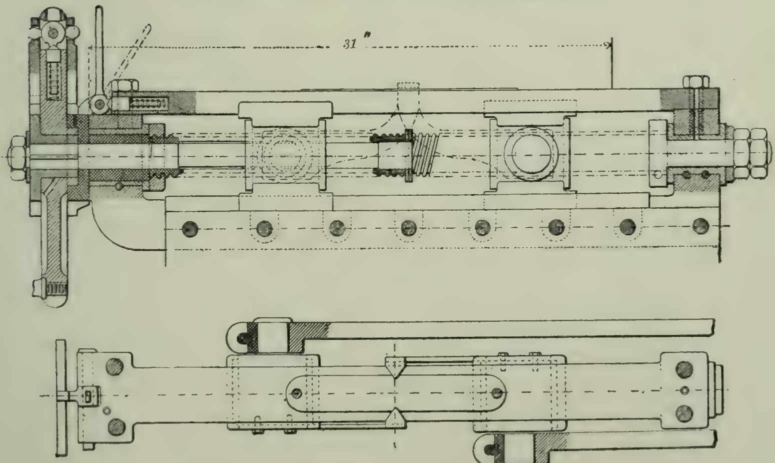


Fig. 22. *With Fine-Screw Adjustment.*



Mechanical Engineers 1900.

Fig. 23. *Starting Gear of the Société Alsacienne with Mechanical Cut-off Gear for 4-Cylinder Compound Locomotives.*

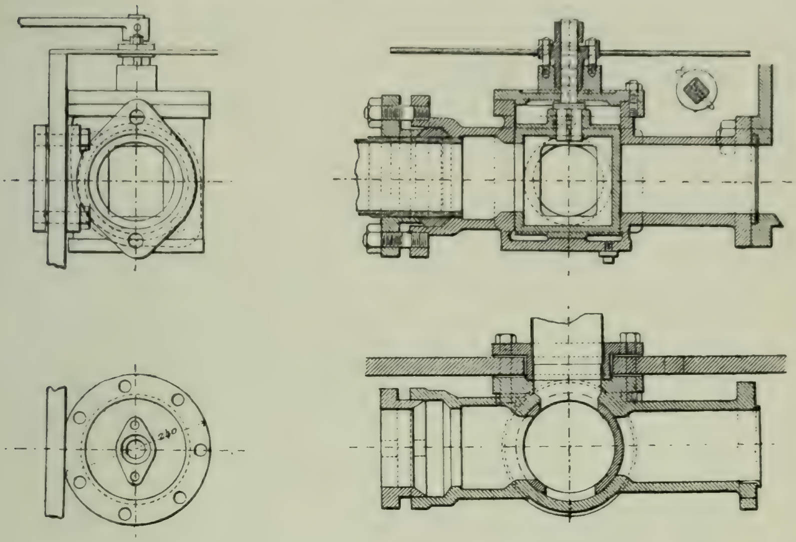


Fig. 24. *Starting Gear of the Est for Compound Locomotives.*

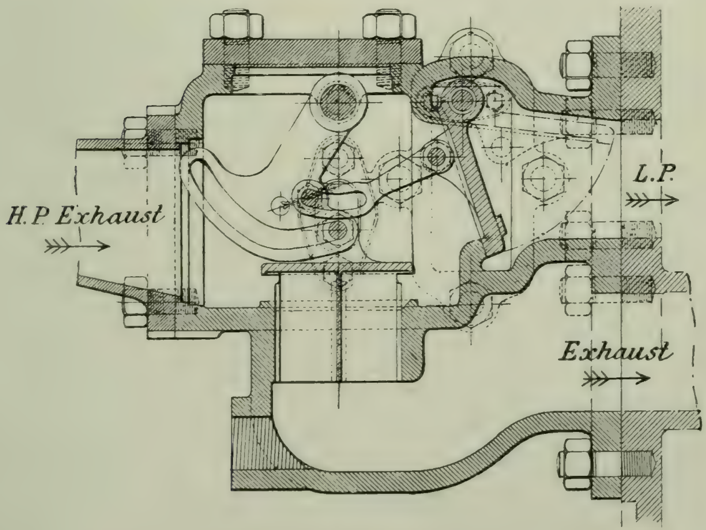


Fig. 25. *Nos.* 2861—2911, *Nord.* 1877 *Type.*

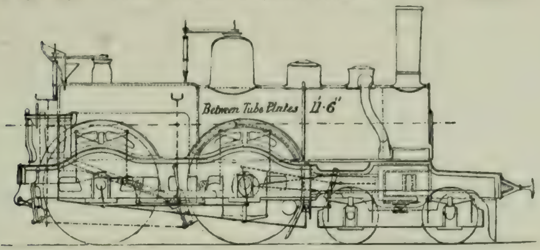


Fig. 26. *Nos.* 939—998, *Ouest.* 1889 *Type.*

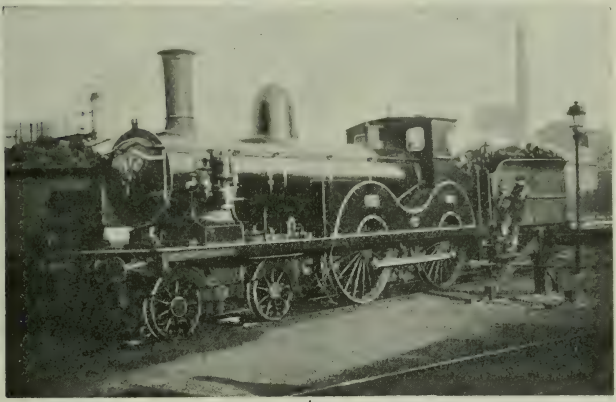


Fig. 27. *Nos.* 2602—2620, *État.* *Bonnefond's Valve-gear.*

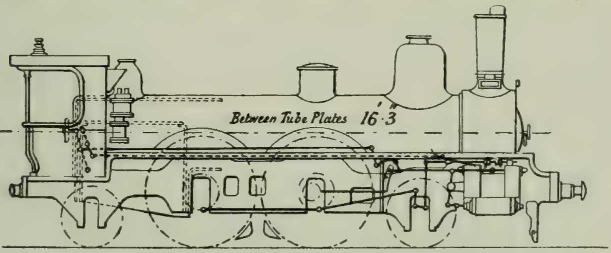
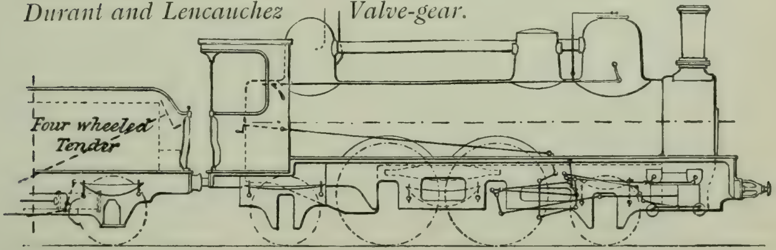
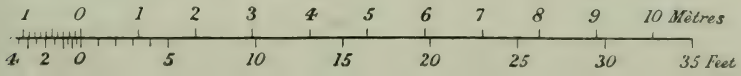


Fig. 28. *Nos.* 576—583, *Paris-Orléans.*

Durant and Lencauchez Valve-gear.





FRENCH LOCOMOTIVE PRACTICE.

Fig. 29. *Nos.* 112—400, *Paris-Lyons-Méditerranée.*

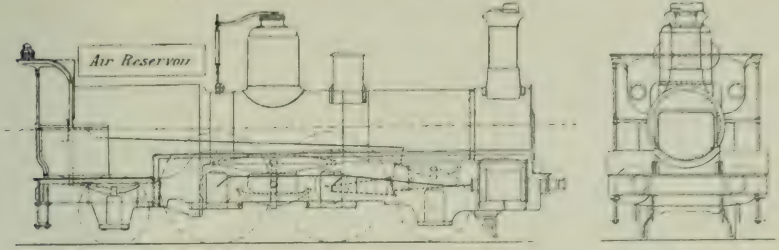


Fig. 30. *Paris-Lyons-Méditerranée. Rebuilt with bogie.*

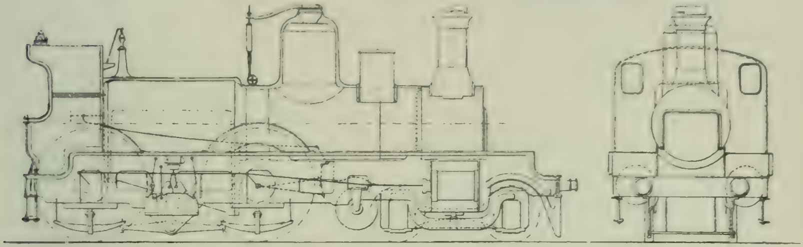


Fig. 31. *Nos.* 801—840, *Est. Bogie with Flaman Boiler.*

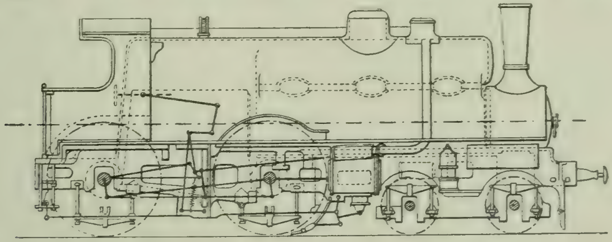
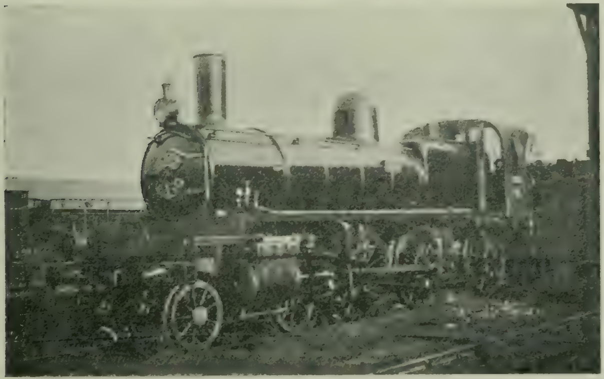
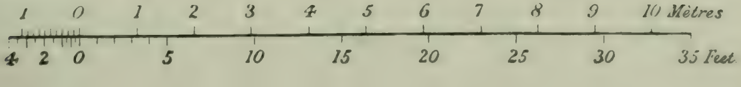


Fig. 32. *Nos.* 2301—2304, *Ouest.*



Mechanical Engineers 1900.


1 0 1 2 3 4 5 6 7 8 9 10 Mètres
4 2 0 5 10 15 20 25 30 35 Feet

FRENCH LOCOMOTIVE PRACTICE. *Plate 53.*

Fig. 33. *Nos.* 4046—4075, 4001—4005, 4636—4990, *Nord.*

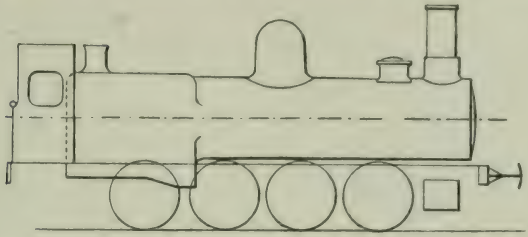


Fig. 34. *Nord. 2-axles-coupled. Bogie. Tank.*

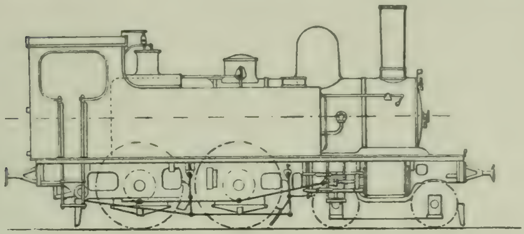


Fig. 35. *Nos.* 221—230, *État. Van.*

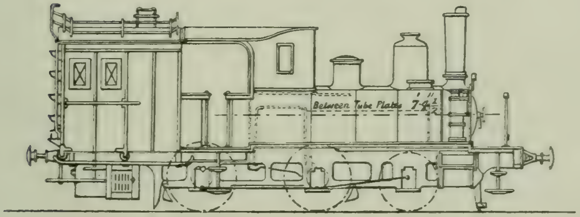
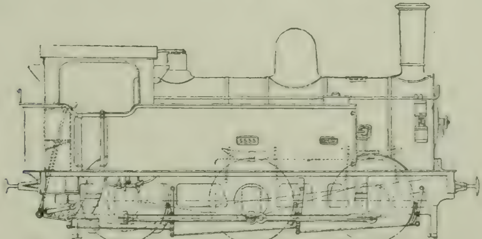
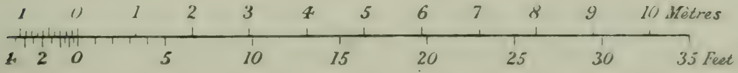


Fig. 36. *Nos.* 3001—3031, 3501—3602, *Ouest. Tank.*



Mechanical Engineers 1900.



FRENCH LOCOMOTIVE PRACTICE. *Plate 54.*

Fig. 37. *Nos.* 3701—3725, *Ouest. Bogie. Tank.*

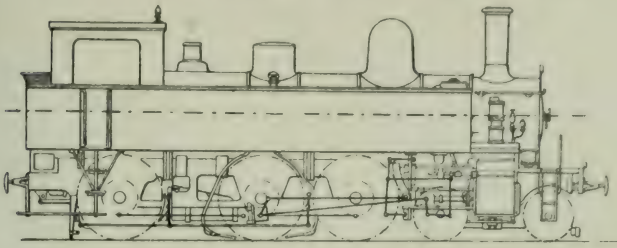


Fig. 38. *Nos.* 684—742, *Est. Tank with a carrying axle.*

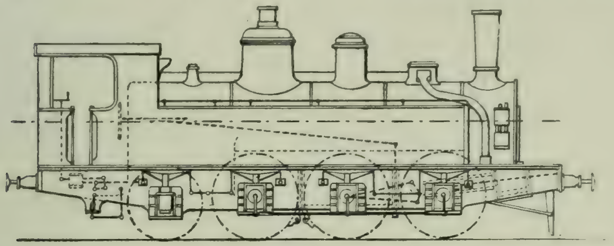


Fig. 39. *Est. Rebuilt with leading-bogie.*

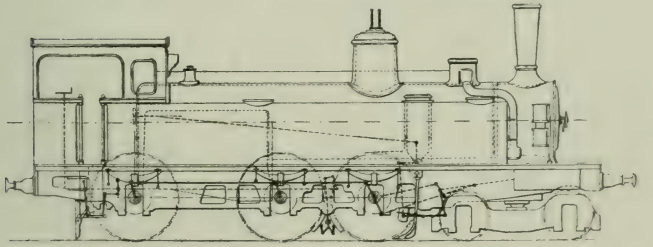
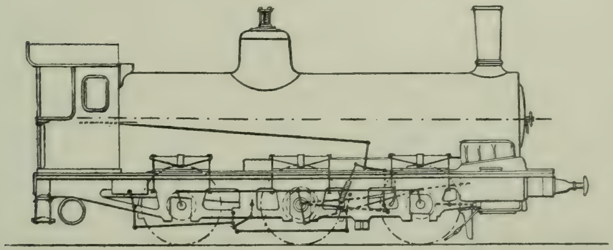
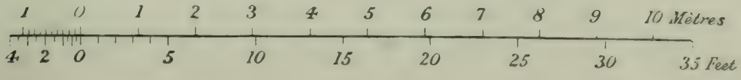


Fig. 40. *Nos.* 1002 *and* 1003, *Est.*



Mechanical Engineers 1900.


1 0 1 2 3 4 5 6 7 8 9 10 Mètres
4 2 0 5 10 15 20 25 30 35 Feet

FRENCH LOCOMOTIVE PRACTICE.

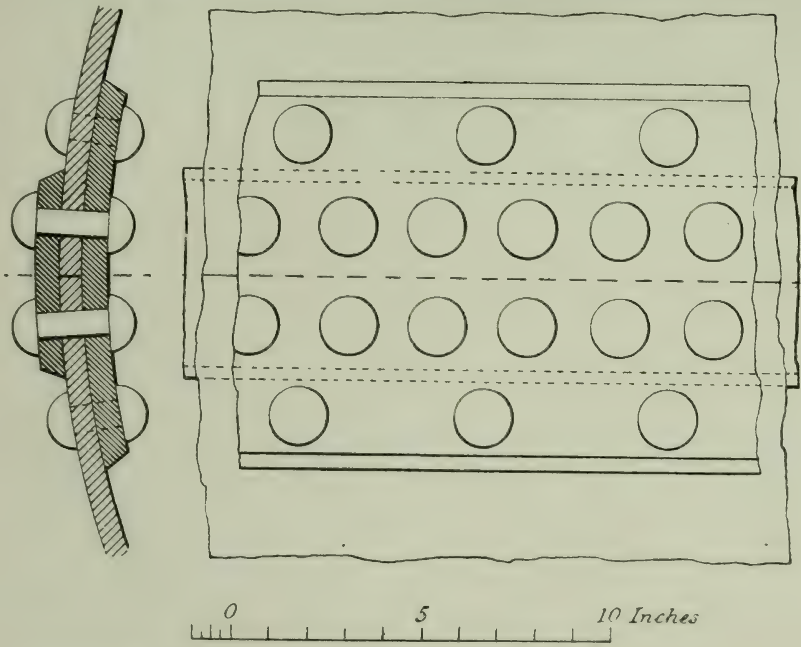


Fig. 41. *Longitudinal Boiler Joint for Unequal Lap.*

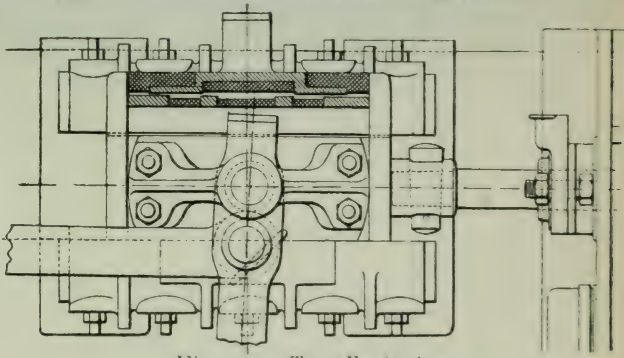


Fig. 42. *Ouest. Valve-Gear showing Valve.*

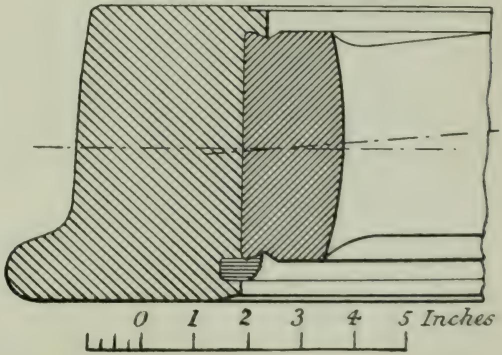


Fig. 43. *Tyre Fastening.*

Mechanical Engineers 1900.

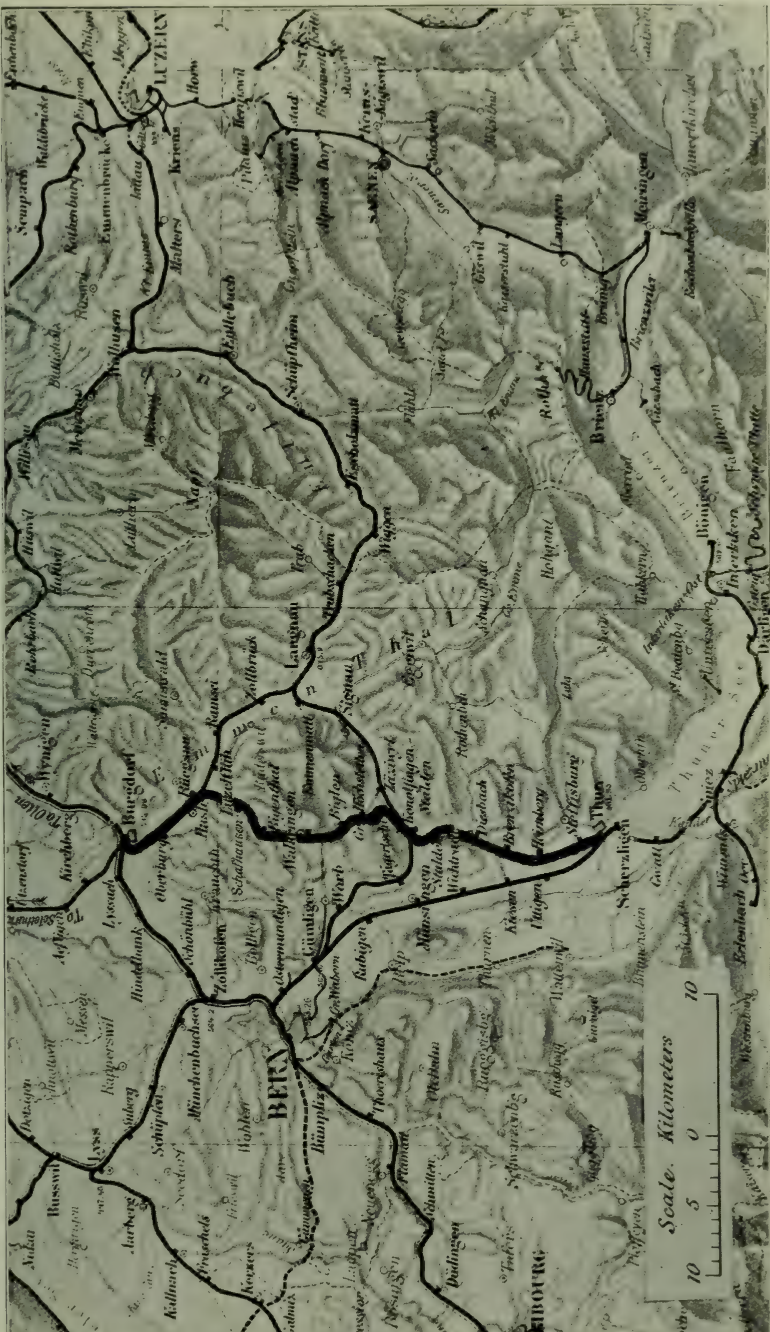


Fig. 1. Map of Swiss Railways.

POLYPHASE ELECTRIC TRACTION.

Burgdorf - Thun Railway.

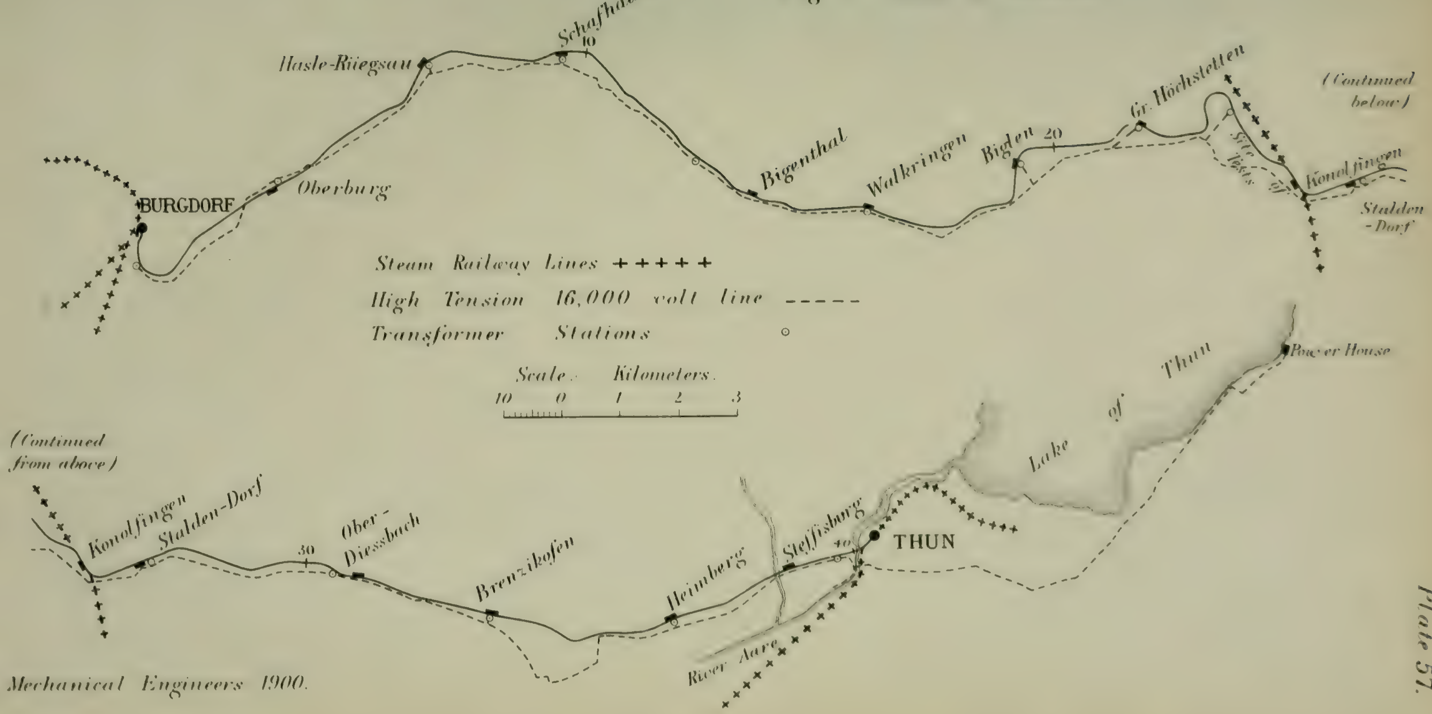


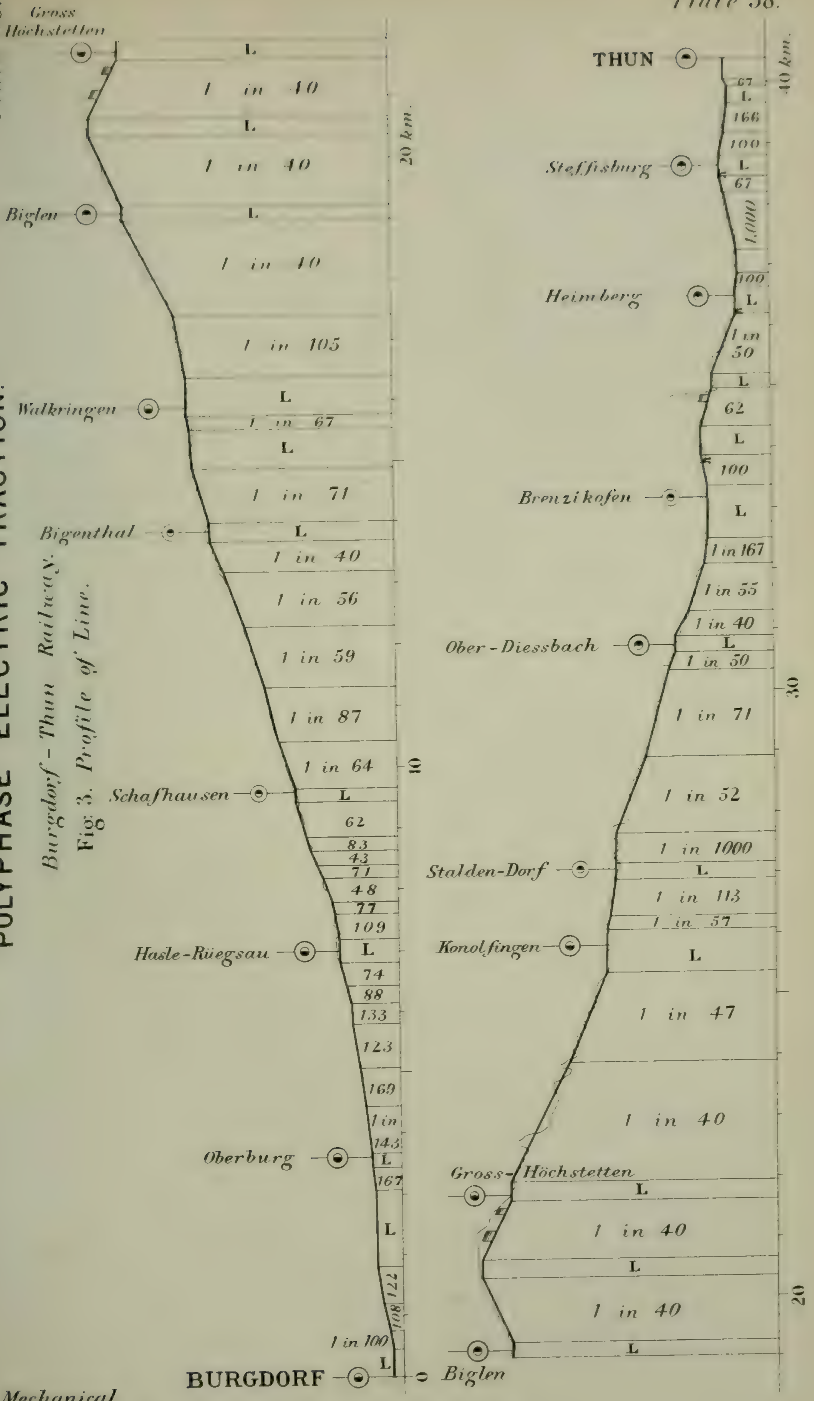
Fig: 2. Map of Route.

Plate 57.

POLYPHASE ELECTRIC TRACTION.

Burgdorf - Thun Railway.

Fig. 3. Profile of Line.



Mechanical Engineers 1900.

Burgdorf - Thun Railway.

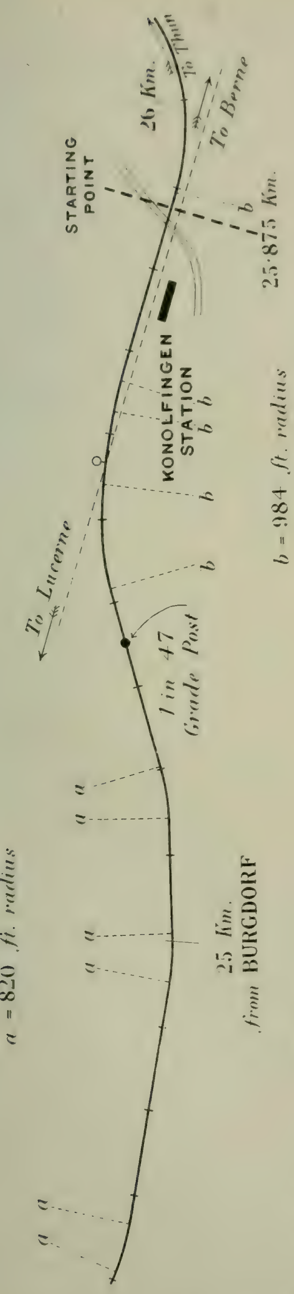


Fig. 4. Trial Track.

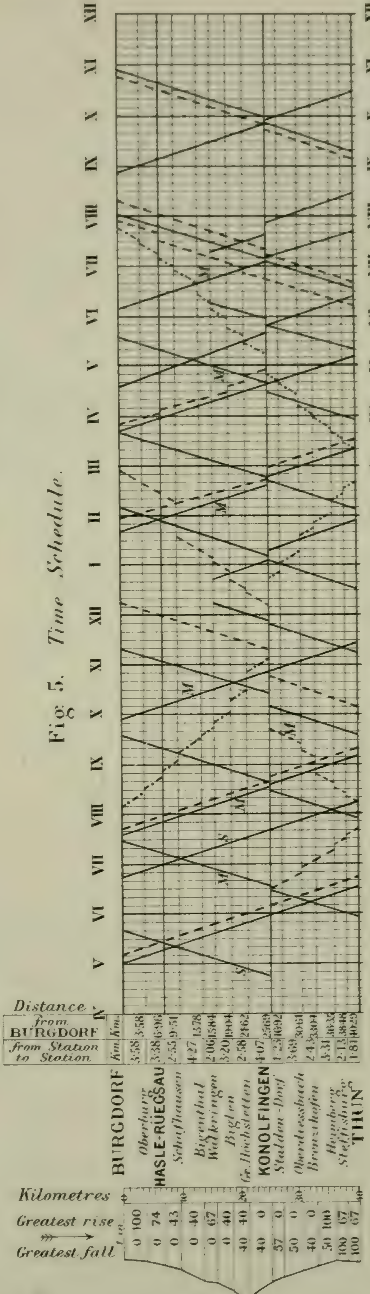


Fig. 5. Time Schedule.

Passenger Trains. —— Supplementary Trains. - - - - Goods Trains. -·-·-·- S. Sunday. M. Mail Trains.

POLYPHASE ELECTRIC TRACTION. *Plate 60.*

Burgdorf – Thun Railway.

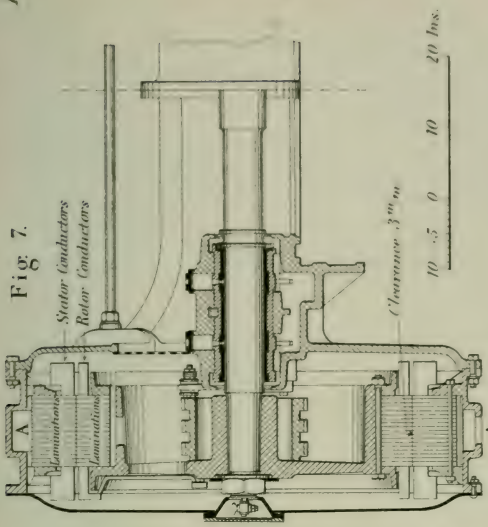


Fig. 7.

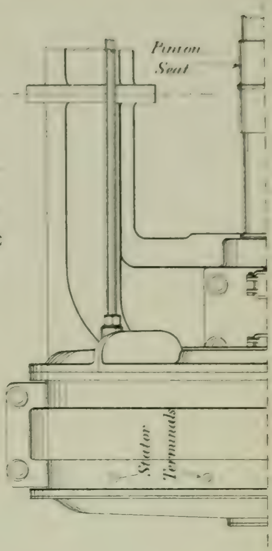


Fig. 8.

150 HP. Motor for Locomotive.

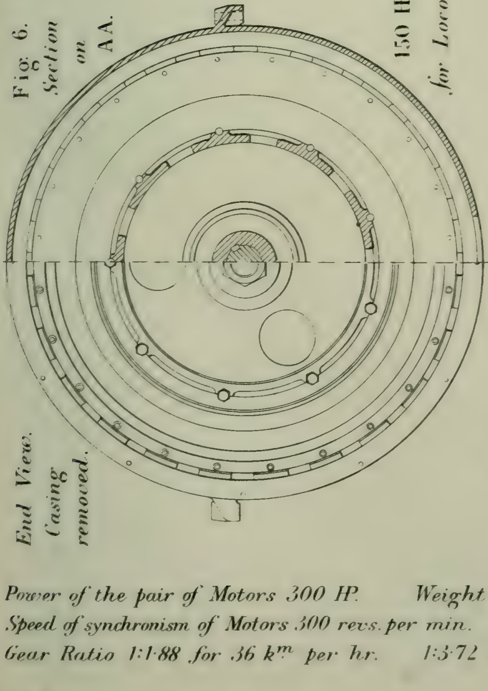


Fig. 6. Section on AA.

End View. Casing removed.

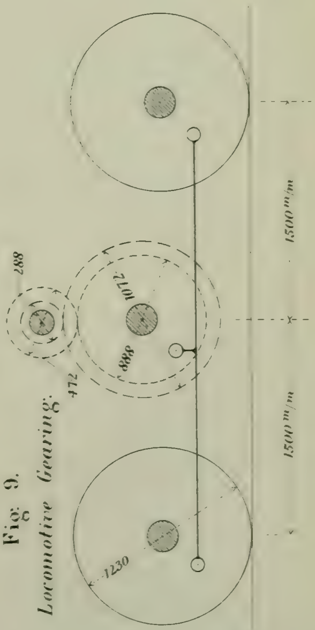


Fig. 9. Locomotive Gearing.

Power of the pair of Motors 300 HP. Weight of Loco. complete = 29·6 tons.
Speed of synchronism of Motors 300 revs. per min. Diam. of Driving Wheels = 1230 m/m
Gear Ratio 1:1·88 for 36 km per hr. 1:3·72 for 18 km per hr.

Burgdorf-Thun Railway.

Fig. 10. *Locomotive with Cab removed.*

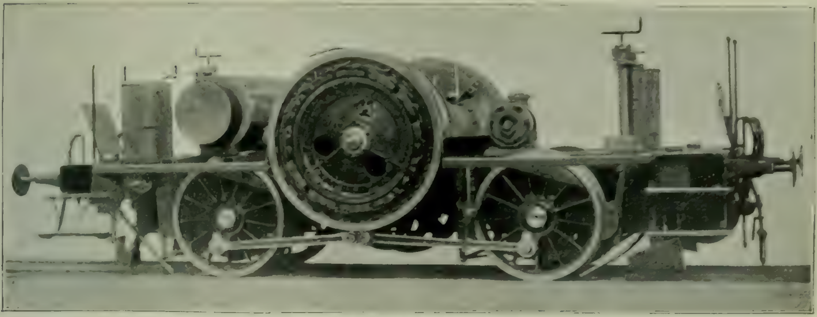


Fig. 11. *Motor Car.*

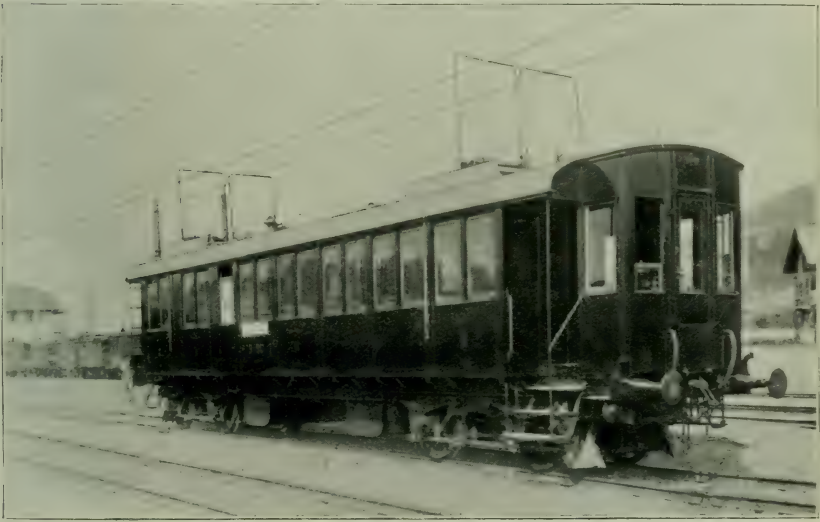
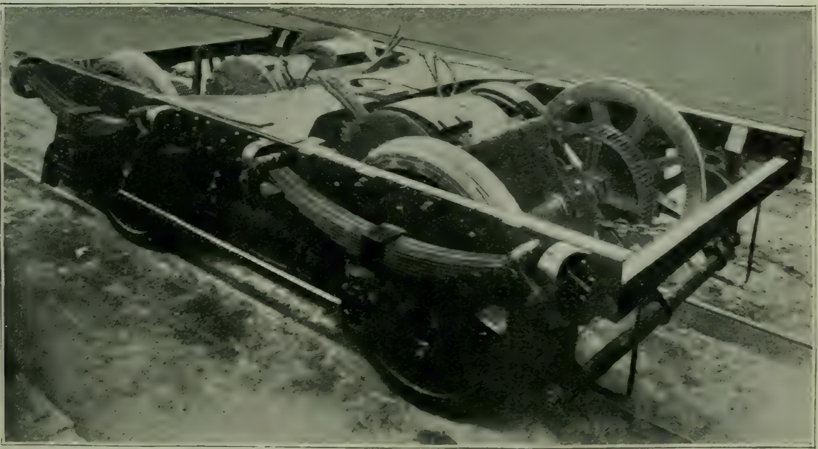


Fig. 12. *Double-Motor Truck.*



POLYPHASE ELECTRIC TRACTION.

Burgdorf-Thun Railway. Motor Car.

Fig. 13.

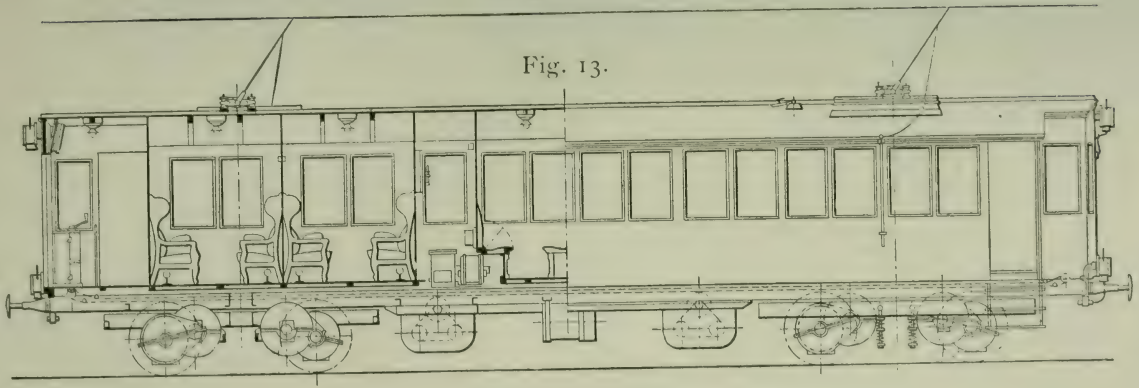


Fig. 14. *Plan from below.*

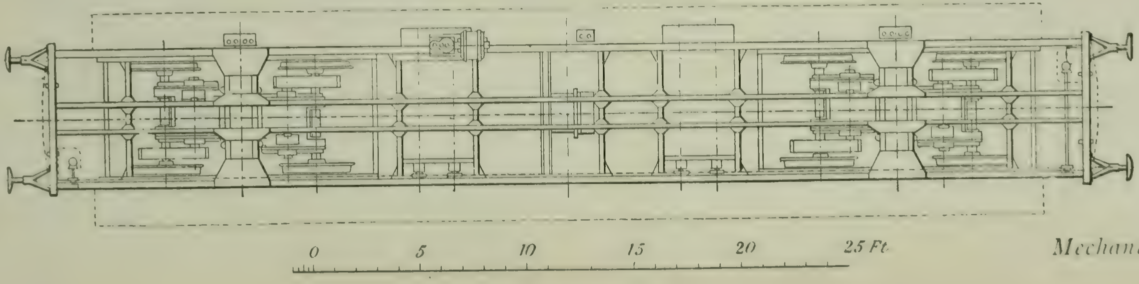
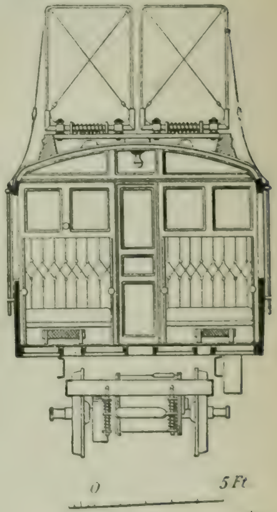


Fig. 15.
Transverse Section.



Mechanical Engineers 1900.

Plate 62.

Plate 63.

POLYPHASE ELECTRIC TRACTION. *Plate 63.*

Details of Suspension for 64 H.P. Motor.

Fig: 16.

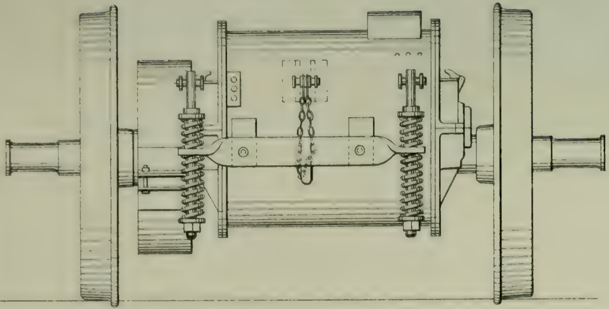


Fig: 17.

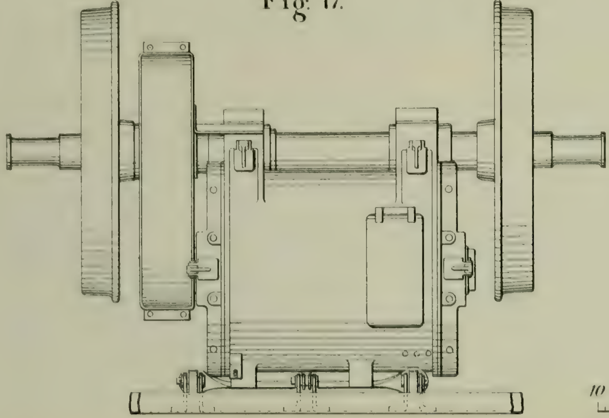
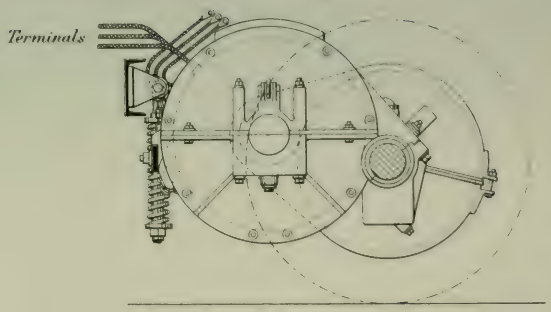
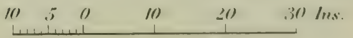


Fig: 18



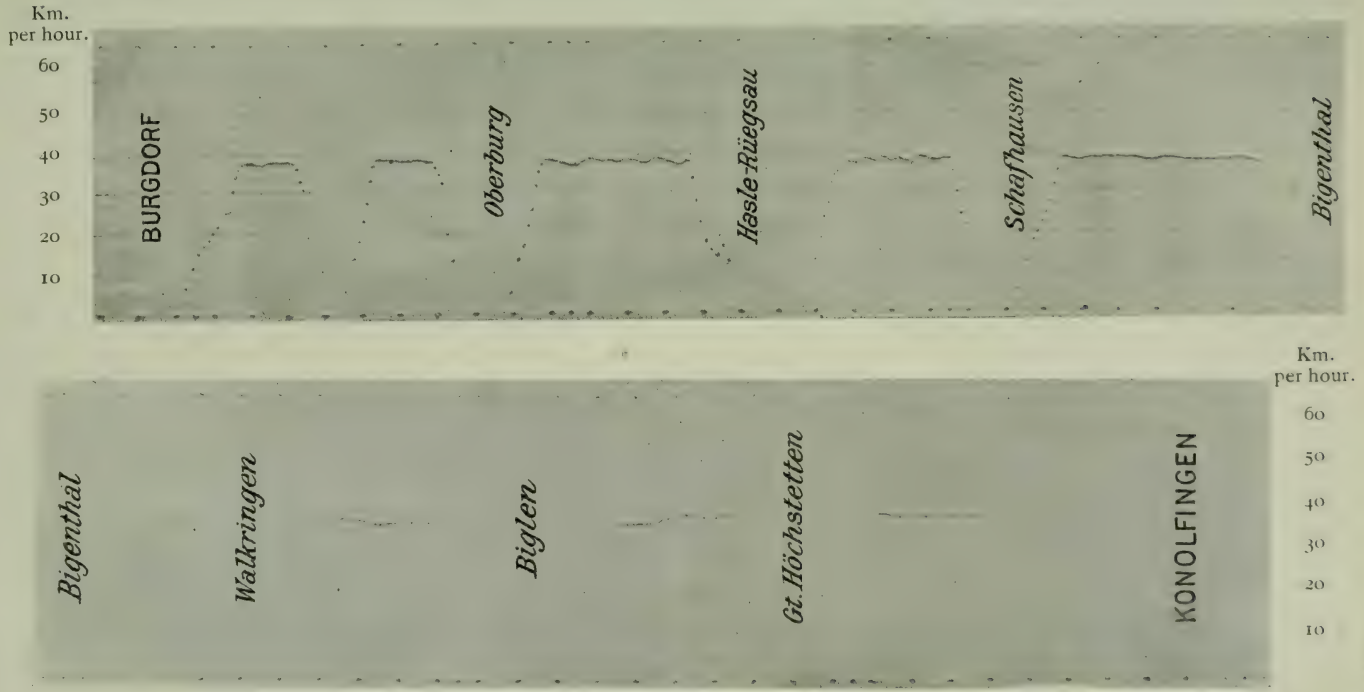
Revolutions of Motor	600	*per min.*
Frequency	40	*" second*
Nº of Poles	8	
Tension	750	*Volts*
Diam. of Pinion	224	*m/m*
" " Gear Wheel	664	*"*
Gear Ratio	1:2·96	
Diam. of Driving Wheel	1020	*m/m*
Wt. of Motor with Pinion	1350	*kg.*
" " Gear Wheel	130	*"*
" " Casing	60	*"*
" " Suspension Parts	60	*"*
Total	1600	*kg.*



Mechanical Engineers 1900.

POLYPHASE ELECTRIC TRACTION.

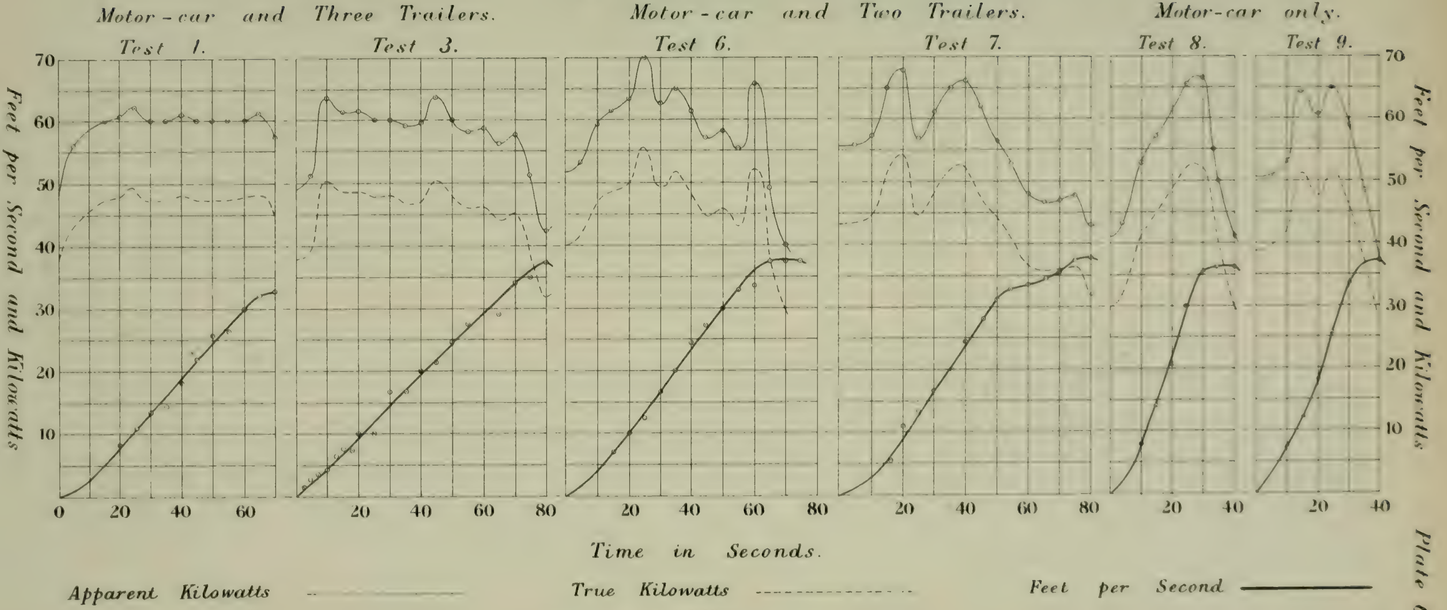
Fig. 19. *Full size Automatic Speed Record taken on a Motor-car between Burgdorf and Konolfingen.*



POLYPHASE ELECTRIC TRACTION.

Burgdorf - Thun Railway.

Fig 20. *Acceleration Tests.*



POLYPHASE ELECTRIC TRACTION.

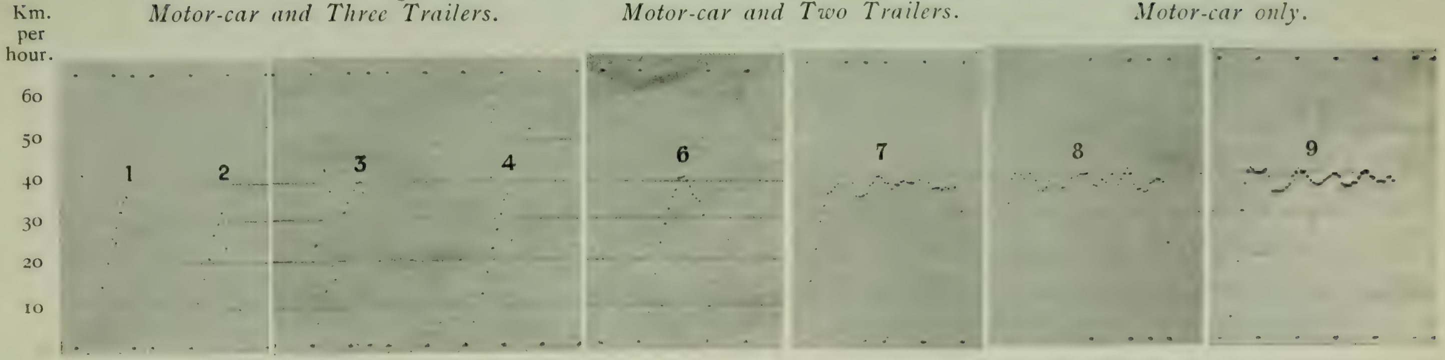


Fig. 21. *Full size Automatic Records of Acceleration Tests.*

Motor-car and Three Trailers. *Motor-car and Two Trailers.* *Motor-car only.*

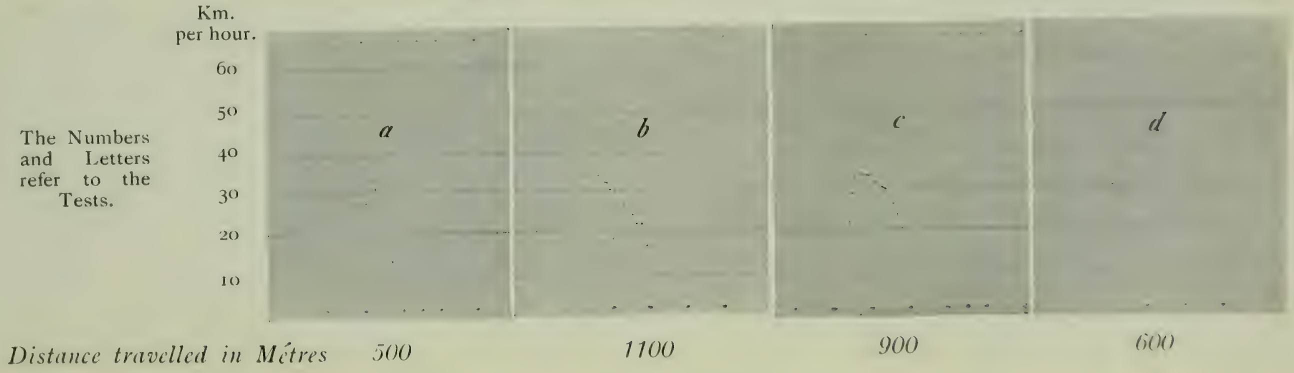


Fig. 22. *Full size Automatic Records of Coasting Tests.*

The Numbers and Letters refer to the Tests.

Fig 23. *Rotor of Polyphase Motor.*

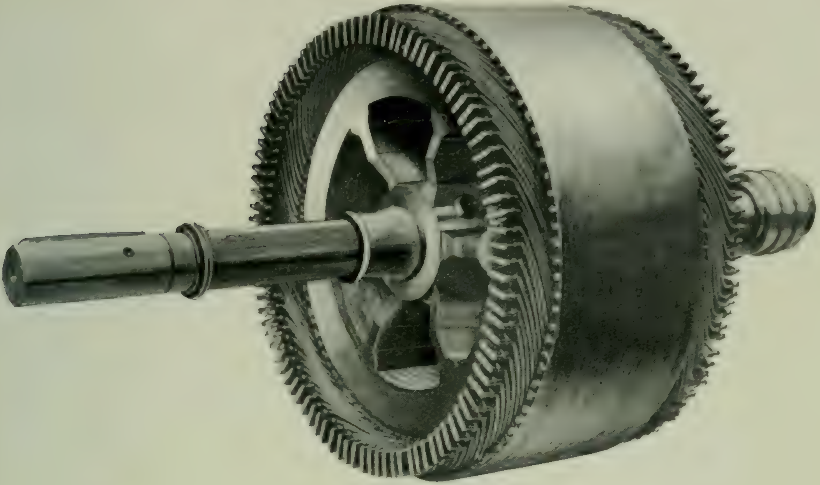
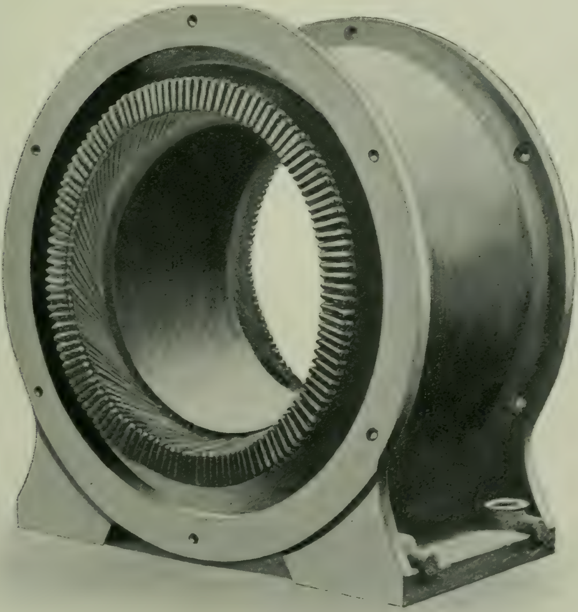
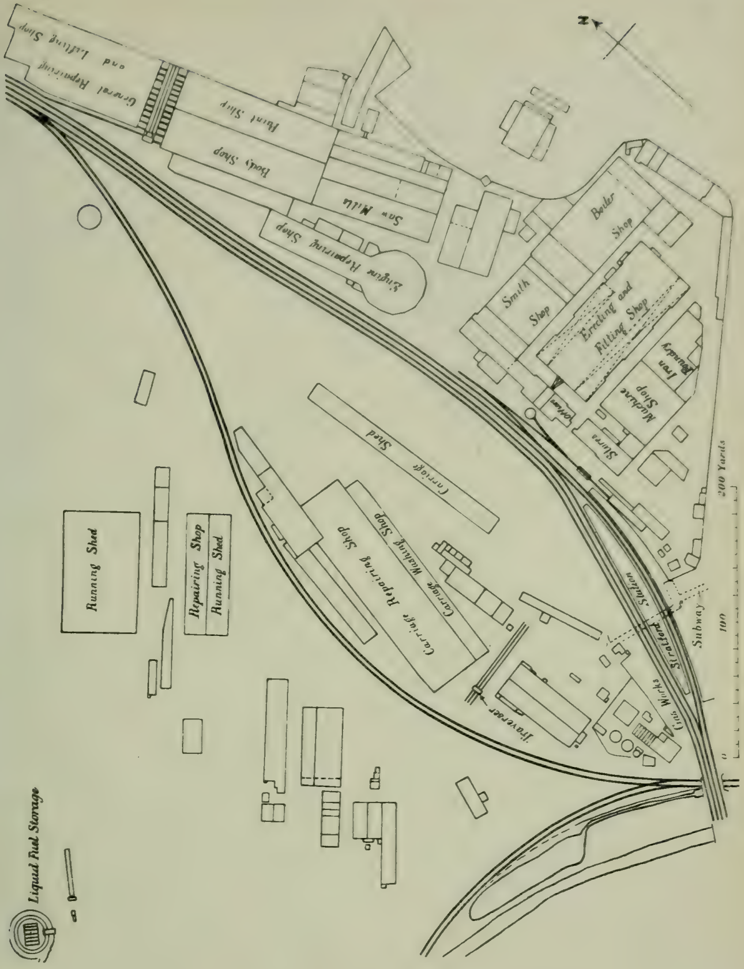


Fig. 24. *Stator of Polyphase Motor.*

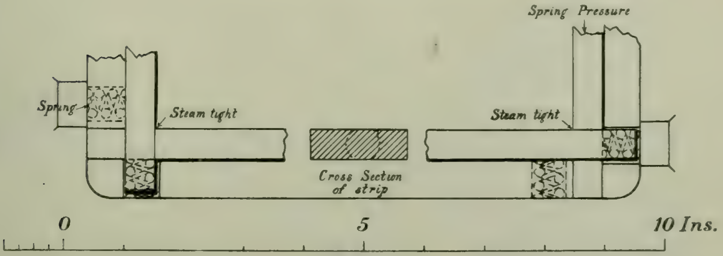


Plan of Great Eastern Railway Locomotive Works, Stratford.



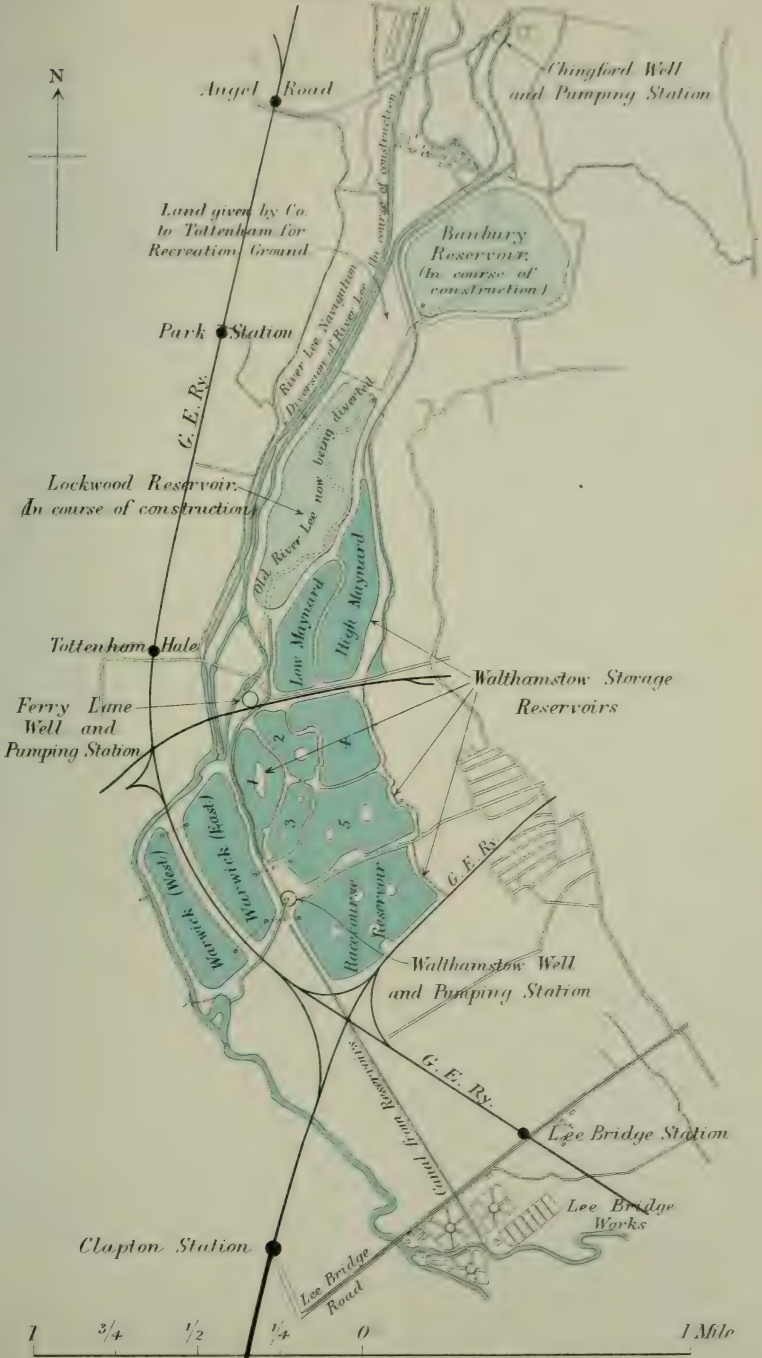
Balanced Slide Valve, G.E.Ry.

A Side and End Helical-Spring for each of the four balancing-strips.



EAST LONDON WATER WORKS, LEE BRIDGE.

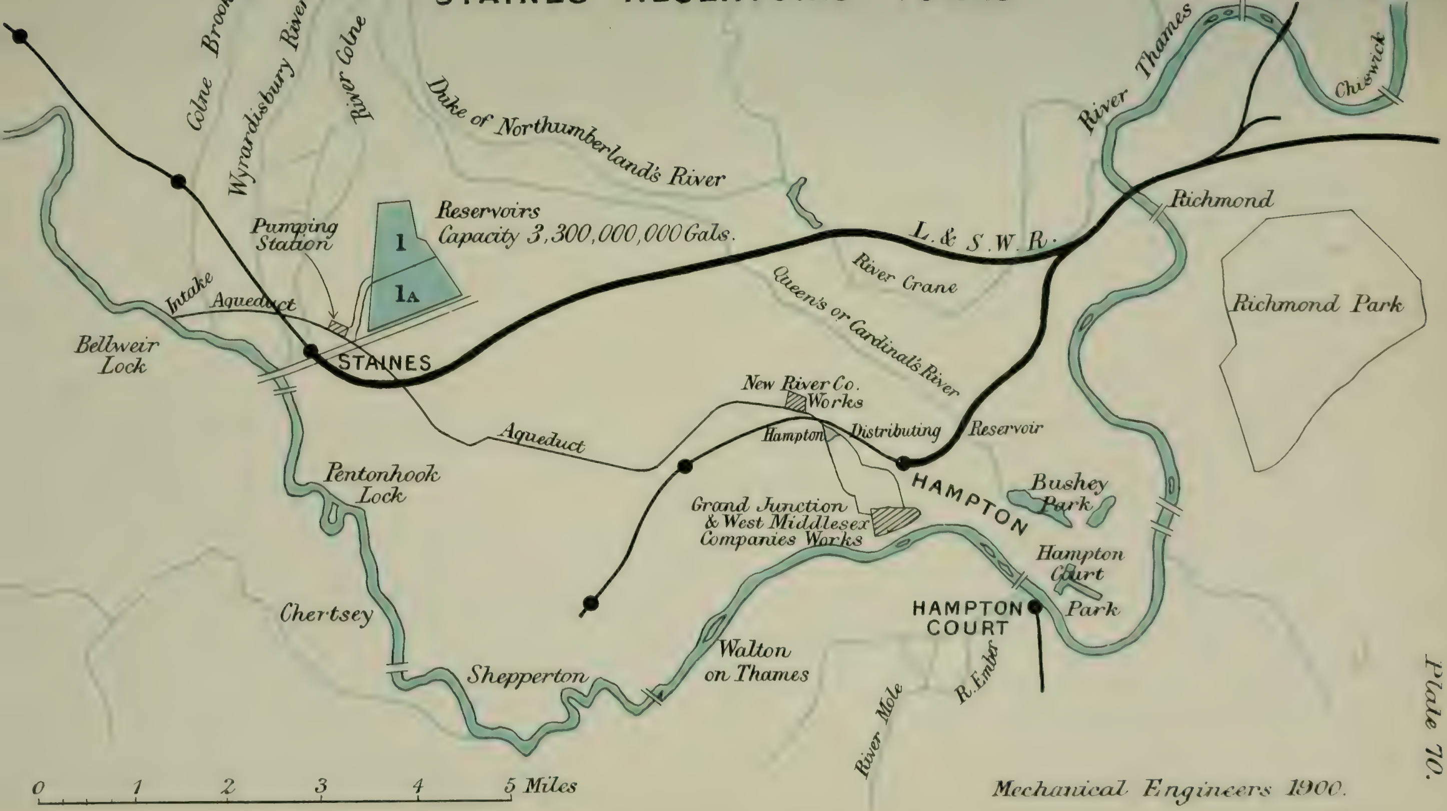
Plate 69.



N
Angel Road
Chingford Well and Pumping Station
Land given by Co. to Tottenham for Recreation Ground
(In course of construction)
Banbury Reservoir (In course of construction)
River Lee Navigation
Diversion of River Lee
Park Station
G. E. Ry.
Old River Lee now being diverted
Lockwood Reservoir. (In course of construction)
Low Maynard
High Maynard
Tottenham Hale
Walthamstow Storage Reservoirs
Ferry Lane Well and Pumping Station
1
2
3
4
5
Warwick (West)
Warwick (East)
Racecourse Reservoir
G. E. Ry.
Walthamstow Well and Pumping Station
Canal from Reservoirs
G. E. Ry.
Lee Bridge Station
Lee Bridge Works
Clapton Station
Lee Bridge Road
1
3/4
1/2
1/4
0
1 Mile

Mechanical Engineers 1900.

STAINES RESERVOIRS WORKS.

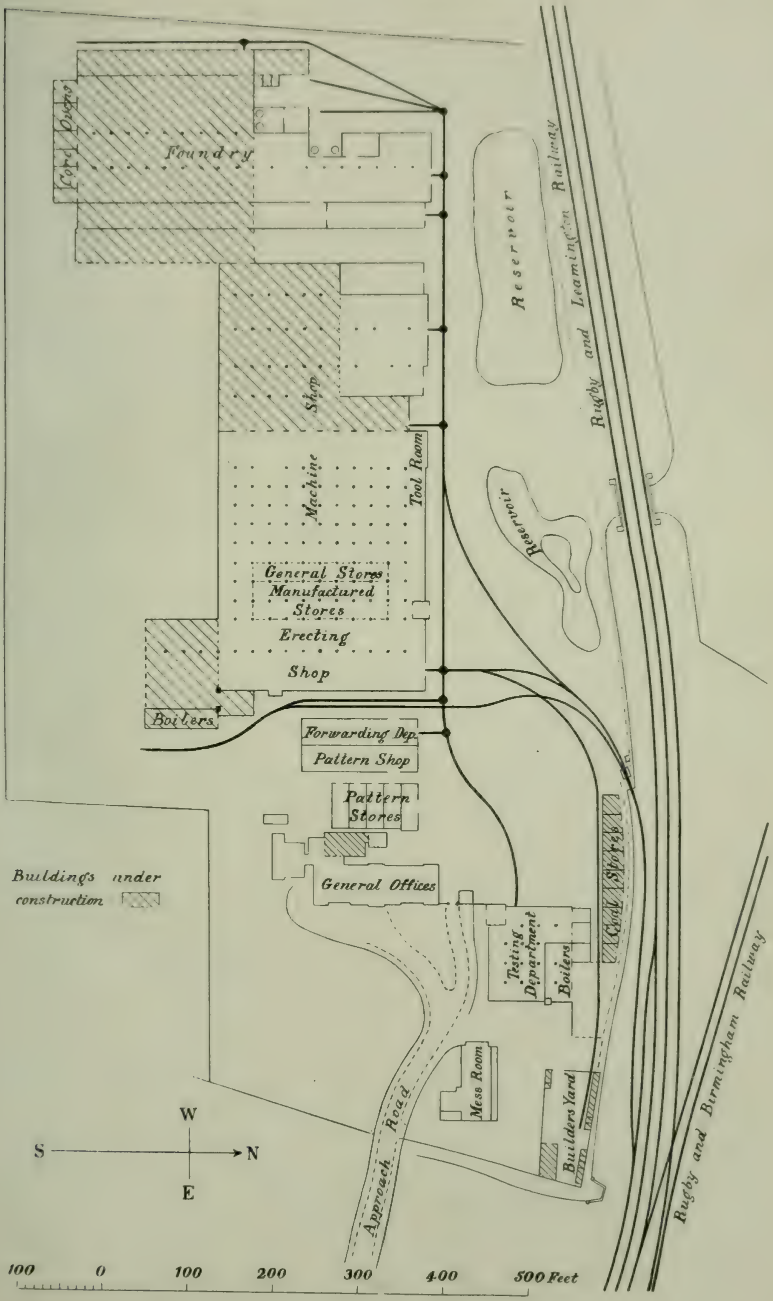


Mechanical Engineers 1900.

Plate 70.

VICTORIA ENGINE WORKS, RUGBY.

Messrs. Willans & Robinson.



Mechanical Engineers 1900.

The Institution of Mechanical Engineers.

PROCEEDINGS.

October 1900.

The October Meeting was held at the Institution on Friday, 19th October 1900, at Eight o'clock p.m.; Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S., President, in the chair.

The Minutes of the previous Meeting were read, approved, and signed by the President.

The President announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following sixty-seven candidates were found to be duly elected:—

MEMBERS.

Barman, Harry Drummond Dawson,	Airdrie.
Bremner, David Alexander,	London.
Davis, Joseph,	Sydney.
Davis, Rayner, R.N.,	H.M.S. "Diana."
Deeble, William Rufus,	Launceston, Tasmania.
Edwards, Albert Edward Alexander,	Birmingham.
Halcomb, Sydney Broughton,	Sheffield.
Hall, William Brasier, R.N.,	London.
Hobson, John Edward,	Manchester.
Hodgson, William,	Manchester.
Hughes, Thomas William Robert,	London.
Lobb, Christopher,	London.
Lovell, Denis Ralph,	Maceio, Brazil.
Marriner, William Wright,	London.

Mathews, Charles James,	Perth, W. Australia.
Mendham, Conrad Field,	London.
Morgan, Charles Hill,	Worcester, Mass.
Whitmore, Frank Leonard,	Erith.

ASSOCIATE MEMBERS.

Alcock, Alfred Edwin,	Rotherham.
Alderson, Charles Albert Heselton,	Alexandria.
Bailey, Harry Dorning,	London.
Boyd, William,	London.
Carr, Harry Oswald,	London.
Casebourne, Ambrose Cubitt,	Newcastle-on-Tyne.
Cash, Ernest William,	Johannesburg.
Catmur, Thomas Stucley,	London.
Drake, Arthur James,	Coventry.
Edleston, Alfred Edward,	Tasmania.
Gash, Lumley Clifton,	Lincoln.
Haywood, Arthur Robert,	Manchester.
Hutchinson, Richard John,	London.
Johnston, Charles Morison,	Shrewsbury.
Jones, Frank Harding,	London.
Jones, Stanley Hunter,	London.
Kersey, Alfred Thomas John,	Swindon.
Marks, Gordon Cumming,	Rochester.
Morton, John Henry,	Buenos Aires.
Neilson, Robert Morrison,	Manchester.
O'Reilly, Francis Joseph,	Brighton.
Pott, George Tom,	Lagos.
Price, Rowland,	Ishapore, India.
Prockter, George Harold, R.N.R.,	Liverpool.
Seabrook, Arthur Hugh,	London.
Smith, Montague Howard,	Banbury.
Steel, Thomas John,	Liverpool.
Stephenson, Alfred,	Shipley, Yorks.
Vigers, George Alexander,	London.
Vines, Charles Granville,	Kimberley.

Ward, Joseph Philip, . . .	Eshowe, Zululand.
White, Daniel Hubert, . . .	London.
Willis, Edward, ...	London.

ASSOCIATES.

Allen, Clarence Edgar, . . .	London.
Page, Davidge, ...	London.
Salomons, Sir David Lionel Goldsmid-Stern, Bart., ...	London.

GRADUATES.

Bagg, Henry Arthur,. . . .	London.
Bazin, John Ralph, ...	Doncaster.
Boulton, Charles Valentine, . .	London.
Box, Wilfrid Leonard, . . .	London.
Calvi, Alberto Ulisse, . . .	London.
Edwards, John, ...	Berlin.
Enock, John Kemp, ...	London.
Eugster, Oscar, ...	London.
Headley, St. John Barrow, . .	Kingston-on-Thames.
Lakin-Smith, Clifford, . . .	Winchester.
Melland-Smith, Hubert Rawson, . .	London.
Thompson, Edward Horace, . .	London.
Yates, Donald Russell Martin, . .	Erith.

Transferences.

The President further announced that the following five Transferences had been made by the Council :—

Associate Members to Members.

Kerr, Alfred Ernest Campbell, . .	Ballarat, Victoria.
Sharpley, George Ruston, . . .	Lincoln.

Graduates to Members.

Bailey, Wilfred Daniel, . . .	Buenos Aires.
Wesley, Joseph A., ...	Lincoln.

Associate to Associate Member.

Peters, Lindsley Byron, ... London.

The President announced that the following letter had been received from the Society of German Engineers, which the Council thought should be communicated to the Meeting with the view of affording individual Members the opportunity of taking any action they might desire in regard thereto:—

Verein deutscher Ingenieure.
43 Charlottenstrasse, Berlin.
July 1900.

Dear Sir,

German engineers recognise the urgent necessity of having a reliable technical dictionary, especially in the three principal languages, viz., English, German, French. On account of this the Society of German Engineers (Verein deutscher Ingenieure) has taken up the question how to produce such a dictionary. The Society would readily spend time and money for this purpose, if this aim could thereby be attained. But this will only be possible, if our colleagues in England, the United States, and France give their assistance. For this end we appeal to the technical and scientific societies at home and abroad. In case of consent we venture to suggest that the societies should select suitable members, by the aid of whom the editor of the dictionary, who will be appointed by our Society, would be brought into touch with such scientific and industrial men as are willing to furnish the technical expressions appertaining to their special branches.

It must however be mentioned, that the above detailed collaboration of the technical societies and the scientific and industrial circles is expected to be rendered gratuitously, as otherwise the expenses would become too heavy. On the other hand, no monetary or other contribution to the work is demanded.

We beg to ask whether the Institution of Mechanical Engineers would be willing to assist as above explained, in regard to the English part in the compilation of an international technical dictionary.

Yours respectfully,
Verein deutscher Ingenieure,
Th. Peters.

The Secretary,
The Institution of Mechanical Engineers, London.

The President added that the Council wished to encourage the German Society to attain their object; but they felt this to be a matter for the Members to discuss, and that the Council as a body could not take any action upon the letter. A reply had therefore been sent to the German Society, saying that their letter would be placed before the Members for enabling them to offer voluntary assistance in the direction indicated.

Professor Robert H. Smith urged the great importance of the subject which had been brought before the notice of the Institution by the German Society of Engineers. For many years he had attempted to read engineering subjects in other languages, and endeavoured to express in English what he had read. For the last thirty years he had from time to time made attempts to use technical dictionaries in that direction, and it was hardly an exaggeration to say that upon no single occasion had he obtained any assistance from any technical dictionary to which he had been able to refer. It was a great pity that technical people in different countries could not be helped to communicate freely with one another by a really authentic dictionary. The ordinary dictionaries for general literary purposes he thought were very good; but surely in technical subjects the need of such help was necessarily a great deal more strongly marked than in general literature. He expressed his regret that the Council could not see their way to promise help in the name of the Institution for this highly desirable object. The project he thought would be a great deal improved by including Italian, in which language there existed a great deal of admirable engineering literature.

The President said, although he had not been present at the Council Meeting when the matter was discussed, he was quite sure there was no want of sympathy on the part of the Council with the object of the movement. The only question was as to the best way of giving effect to it. The Council thought that, as the request made to them was that suitable members of the Institution should be selected, by whose aid the editor of the

(The President.)

dictionary could be brought into touch with such scientific and practical men as were willing to furnish the technical expressions, their best course was to invite the members to take up the matter individually. Amongst the members of the Institution he thought there would not be wanting those who were as strongly in sympathy with the movement as Professor Smith, and who would be ready to give their help. It would be quite understood that there was a difference between a selection made by the Council and the voluntary offers of assistance from the members; but it would be a matter of regret if there should be any erroneous idea that the Council were at all out of sympathy with the object referred to in the letter.

Mr. Bryan Donkin, Member of Council, quite agreed with the remarks of Professor Smith. The work which the German Society proposed was a most valuable one. Personally he would be very glad to take up the subject of Steam; and perhaps Professor Smith and other members would kindly say what branches they would undertake, and thus bring the subject to a practical issue.

The President wished to add that if any member of the Institution, who was ready to help, would inform the Secretary to what branch of mechanical science he would lend his aid, his name could be communicated to the German Society without his being appointed by the Institution as a body.

Mr. J. Macfarlane Gray said there were many members of the Institution who were able to help, and yet were diffident about giving their names, thinking that the help which they could render would be proportionately little. Could it not be arranged that before the sheets of the intended publication were prepared for passing through the press they should be placed in the reading room of the Institution for a few weeks? If this were made known to the members, he had no doubt a number of them would call and examine the proofs, and communicate their observations to the Secretary.

Mr. Donkin suggested that a fortnight might be sufficient.

Mr. Macfarlane Gray thought a month would be better, because many members would then help, who would not otherwise have an opportunity of doing so.

The President thought Mr. Macfarlane Gray's suggestion was highly practical, and it would be communicated to the German authorities.

Mr. James T. Bateman asked how the Council proposed to deal with the commercial side of the question: whether if the book were published it would be open to the general public throughout the whole of the country; or whether it was intended to be connected only with the various Institutions. He wished also to know what precautions would be proposed for preventing such a book from being made public for commercial purposes.

The President said he understood from the letter that the volume was to be published for general circulation by the Society of German Engineers. He supposed the Society which promoted the object and undertook the responsibility would be the owners of the dictionary, and that it would be a book for general sale and general use, and he presumed the German Society would be the owners of the copyright.

Mr. Bateman asked whether the book would be sold at a profit to the Society.

The President said there was no indication of that intention in the letter.

Mr. Sidney Tebbutt asked whether the Society of German Engineers desired to codify the names of the parts of all the various machines which were in existence, or whether they wished merely to get the names of objects common to general engineering. Most

(Mr. Sidney Tebbutt.)

engineers had knowledge of special machines, and would no doubt be glad to give any help they could.

The President said it might be convenient, as the evening was getting on, and there was a paper to be read, if a note of the discussion upon the letter were circulated to the members of the Institution. It might interest those who were not present to know what the object of the letter was, and what the desire of the Council was in regard thereto, because it was not likely that the Institution would be able to discuss it further during the meetings. The great thing was to get all the help they could in carrying out in the best way what he thought they would all agree was a desirable object.

The following Paper was read and discussed:—

"Observations on an improved Glass Revealer, for studying Condensation in Steam-Engine Cylinders, and rendering the effects visible"; by Mr. Bryan Donkin, *Member of Council*, of London.

The Meeting terminated at Twenty Minutes to Ten o'clock. The attendance was 141 Members and 55 Visitors.

OBSERVATIONS ON AN IMPROVED GLASS REVEALER, FOR STUDYING CONDENSATION IN STEAM-ENGINE CYLINDERS, AND RENDERING THE EFFECTS VISIBLE.

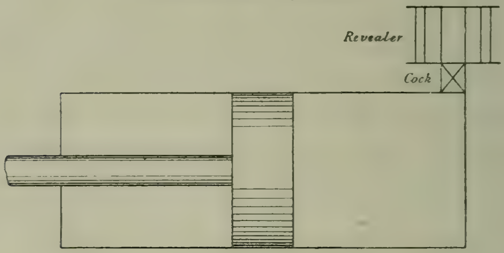
By Mr. BRYAN DONKIN, *Member of Council*, of London.

Some years ago the author introduced a small glass instrument named by Hirn a " Revealer," for studying the Condensation of Steam in an Engine Cylinder. Since then some improvements have been made, and the following results obtained.

A revealer was placed on the top of both the high and the low-pressure cylinders of a compound steam-jacketed vertical condensing beam engine, working in a factory at a speed of about 35 revolutions per minute. The diameter of the low-pressure cylinder is 26 inches with 3 feet stroke, and that of the high-pressure cylinder $7\frac{5}{16}$ inches with 14 inches stroke.

General Description.—Each revealer has two cylindrical glasses, Plates 72 and 73, fixed concentrically one inside the other, thus forming a hot-air jacket for the inner glass, with an annular space of 10 millimètres (0·4 inch) between them. The inner glass cylinder is smaller in diameter than formerly, the connecting pipe to the motor cylinder is straight, and the cock and pipe much larger, so that the connection is more direct. Inside the inner glass is a small cast-iron cylinder. All the external metal and glass surfaces are well covered with removable thick non-conducting material to diminish radiation. The object of the instrument is to reproduce as nearly as possible, and render visible, what takes place inside the steam cylinder, and which is necessarily concealed. No vessel, such as a revealer, exterior to the cylinder, can be under exactly the same conditions as the internal parts, because the cylindrical portion of the latter is cleaned by the piston at every half revolution, and the clearance surfaces are greasy. Nevertheless, the effects of condensation, as shown by the revealer, may be within 5 to 15 per cent. of the truth, and all results can be accurately seen, magnified, and studied. In all steam cylinders, condensation takes place on the internal walls when working with saturated steam. In this revealer, under the above conditions, very fine globules of water, the results of condensation, will be seen, close together, the appearance of which the author will first endeavour to describe for the low-pressure cylinder.

Fig. 1.—Diagrammatic sketch showing position of Revealer on Horizontal Cylinder.

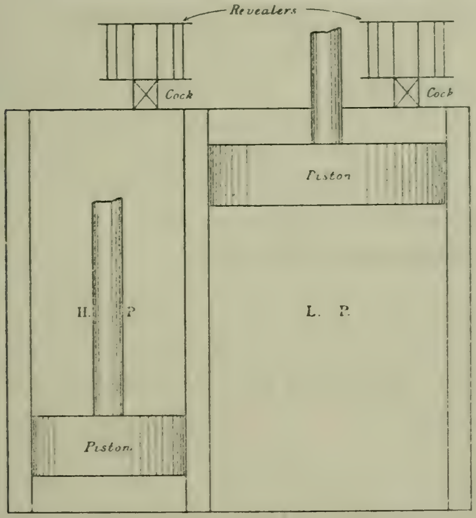


Revealer on the Low-Pressure Cylinder.—The modifications of the improved revealer have caused a great reduction in the size of the minute globules on the glass walls, as compared with those shown in former experiments. After the revealer has become comparatively warm, and when the steam is first admitted into it from the low-pressure cylinder, the globules, from 1 to 2 millimètres (0·04 to 0·08 inch) in size, are much larger than those seen after working about 10 or 15 minutes, when all the parts have had time to acquire a normal temperature. Commencing with the steam stroke, the first result observed, when the steam is admitted to the revealer, is a light and not very dense cloud or white fog coming up from the engine cylinder. This is precipitated upon the hot internal glass and cast-iron walls, and is seen as very fine globules or particles of moisture or condensation.

This cloud is sufficient to obscure a light placed on the opposite side of the revealer. Re-evaporation then rapidly follows before the end of the steam stroke. On the opening of the exhaust-valve, the cloud passes quickly off into the cylinder, and the glasses become quite transparent. A good illumination renders the incoming and outgoing clouds of mist quite visible.

Each time the steam enters, a large number of very small globules, at about equal distances from each other, are immediately seen upon the glass walls. These are from 1-20th to 1-25th of a millimètre (0·002 to 0·0016 inch) in diameter, or less, Plate 72, and are distributed in a fairly uniform manner over the surfaces. The time occupied by the deposition of the globules, and their re-evaporation, is perhaps a tenth of a second. Before the end of the steam stroke, the duration of which is about half a second, and before the exhaust valve opens, the smaller globules, 1-25th of a millimètre in diameter, are all evaporated. During the exhaust stroke, the larger globules are also re-evaporated

FIG. 2.—Diagrammatic sketch showing positions of Revealers on Cylinders of Vertical Beam Engine.



but not so quickly. The internal surfaces are sometimes quite dry, and at other times a few drops of moisture remain on them.

To facilitate the study of these minute condensed globules or wet particles on the inside of the inner glass, a microscope is used, and the glass and iron walls well illuminated. It is interesting to watch not only the formation of the globules, but also their rapid disappearance by evaporation. Any change in the working conditions of the engine, by altering the expansion or speed, is at once detected. The globules change in diameter, becoming larger or smaller than before, probably as the difference of temperature between the walls and the steam is increased or diminished. Very soon however the glass walls take up a certain temperature, and constant conditions again prevail, differing only in the size of the globules from those previously seen. By artificially cooling the outside of the short iron connecting pipe between the glass revealer and the cylinder with cold water and a sponge, the fog or cloud on admission of the steam at the commencement of the steam stroke is much increased, as is also the diameter of the globules on the internal glass walls. The steam seems to be chilled.

Two other revealers with single glasses, and longer and uncovered connecting pipes fixed on the same end of the same low-pressure cylinder, gave during the same stroke greater condensation and larger globules, with thicker fog inside. This was a result which might be expected.

Condensation on the Cast-Iron, from the Low-Pressure Cylinder.—Inside the inner glass cylinder or revealer, a small cast-iron cylinder was placed, to observe the condensation produced on this metal, and to measure the size of the globules. Vertical and horizontal cross lines one millimètre apart were marked on the outside of this cylinder, forming small areas of one square millimètre, Plate 73. These squares, being visible under the microscope, afford a useful means of estimating the size of the minute globules. The condensation observed was practically the same on the cast-iron as on the inner glass cylinder, both being probably at the same temperature, and touched by the same steam.

The various phenomena may be summarised as follows, after the normal conditions are established, for the low-pressure cylinder.

One revolution.	1. Fog rising from cylinder into revealer . . .	Steam stroke duration about ½ second.
	2. Deposition of moisture and water on glass and metal surfaces	
	3. Rapid re-evaporation during expansion . . .	
	4. Exhaust opens. Fog sinking back to cylinder .	Exhaust stroke duration ½ second.
	5. Glasses quite clear. Surface nearly dry . . .	

Internal diameter of glasses, 67 and 44 millimètres (2·64 and 1·73 inches). External diameter of cast-iron cylinder, 35 millimètres (1·38 inch). Height of glasses and cylinder, 57 millimètres (2·24 inches).

The pressure in the low-pressure cylinder varies a little at different times of the day; the maximum initial is generally about at atmospheric pressure (see Average Diagram, Plate 75). At times, in the revealer, no condensation is visible and no re-evaporation, only very slight fog in and out.

Revealer on the High-Pressure Cylinder.—A second revealer, with double glasses and a small cast-iron cylinder in the centre, was placed on the top of the high-pressure cylinder, and well protected from heat losses. All the general series of effects were the same as those on the low-pressure cylinder during one revolution. The only marked difference seen between the two revealers on the two cylinders was in the size of the condensed globules on the glass and cast-iron surfaces. These were about 1–4th to 1–5th millimètre (0·01 to 0·008 inch), some few being half a millimètre (0·02 inch) in diameter, Plate 72. This means more condensation in this cylinder than in the low-pressure, which agrees with calculation and experiment. The cylinders are jacketed with live steam at a pressure of 60 lbs., or about 4 atmospheres. As the mean working pressure is much lower than in the high-pressure cylinder, there is a much greater difference of pressure and temperature between the jacket and the large cylinder. The jacket is thus more efficient on the low-pressure cylinder, and less condensation is to be expected. This agrees with experimental results. In this way the interiors of the two revealers can be seen and compared at the same time on the top of each cylinder.

To make sure that the varying pressures of steam in the revealers were really the same as in the engine cylinders, two indicators were fixed, one on the top of each revealer and the other on the top of each cylinder, and diagrams taken during the same stroke. The diagrams were exactly the same from the revealers as from the cylinders.

The range of temperature in the high-pressure cylinder is generally about 101° F. or about 56° C., and that in the low-pressure cylinder some 85° F. or 47° C.; but the pressures and temperatures vary somewhat with the work. This double glass revealer, Plates 72 and 73, forms a kind of transparent prolongation of the steam-engine cylinder.

One result of these observations is to prove that there cannot be any thin film of condensation water on the internal surfaces of steam-engine cylinders, whether the cylinder is relatively hot or cold, as there has so often been supposed to be. The difference of temperature between the walls and the working steam seems to affect only the size of the globules of water.

It is very difficult for the eye to follow the rapid and violent movements of fog and small globules of water in all directions on the internal surfaces, and also their very quick and violent disappearance by re-evaporation at exhaust.

It is now generally admitted that condensation of steam in engine cylinders is caused chiefly by the difference of temperature between the internal surfaces and the steam in contact with them, which it should be the object of engineers to minimise. Condensation is reduced in quick-revolution engines, and where dry or superheated steam is used. It assumes various forms, water particles, fog, or globules of different diameters. These seem always to be in rapid motion, and not stagnant. On admission, the internal metal walls are heated by the steam. Other heat changes occur during each revolution, tending to equalise the temperatures between the solid iron, the liquid water, and the gaseous steam.

The temperatures of the 1 and 2-millimètre drops of water have not yet been measured, existing only during say 1-10th of the stroke. Wall temperatures have been taken; and the varying steam temperatures, deduced from the indicator diagram of pressure, are known fairly well during a revolution.

Rotary engines should give less condensation on admission, as compared with the reciprocating types, both working with steam-jackets and with superheated steam.

Steam Revealer with two cylindrical glasses, and internal steam or water-jacketed Cast-Iron Cylinder in centre.—The following further experiments have been made. A small cast-iron cylinder, Plate 74, is fixed in the centre of the revealer, and so arranged that boiler steam can be introduced inside it to raise its temperature, provision being made to drain the water away. Cold water can also be passed through it continuously to reduce its temperature. The mean temperature of this inner cylinder was taken by means of a mercurial thermometer about 2½ millimètres (0·1 inch) in diameter, placed in a hole in the centre of the wall. The steam from the engine cylinder passes at each stroke into and out of the annular space BB, between the cylinder and the inner glass. The fog or condensation on the walls can be observed through the glass cylinder by the eye or a microscope. In this way the small cylinder can be either heated by steam or cooled by water, and the fog effects noted for different temperatures of this small cylinder inside the revealer. To get the mean temperature of steam in the steam-engine cylinder, indicator diagrams were taken, and the mean temperature calculated from the pressures. Thus, when all the conditions are constant, the temperature attained by the small cylinder can at any time be compared with the mean temperature of the steam touching its walls.

Experiment. December 1899. Plates 74 and 75.

The revealer shown in Plate 74 was fixed on the top of the low-pressure jacketed cylinder of the engine, and placed in communication with it. The speed of the engine was about thirty-five revolutions per minute. Boiler steam was admitted into the inside of the small central cylinder, and the revealer was kept going with the power on the engine constant for a given time, until all the working conditions were normal. At a given moment, with the wall at 299° F. or 148° C., the steam was shut off from the jacket, and notes were made of the gradual decrease of the wall temperature, arising doubtless from the exposure of the hotter walls to the cooler steam-stroke, and to the still cooler exhaust-stroke to condenser. This had already been noticed in a preliminary experiment. For indicator diagram see Plate 75. The wall-temperatures were read every minute until a minimum of 197° F. or 92° C. was reached and maintained. The steam was then turned again into the jacket, and the rapid rise of the wall-temperature noted up to 285° F. or 140° C. in about one minute. The wall-temperatures are plotted in Plate 75. In thirty-five minutes the temperature of the cylinder decreased from 299° to 197° = 102° F. or about 2·9° F. or 1·6 C. per minute. The mean temperature of the steam for the two strokes was 168·45° F. or 75·8° C., as explained on Plate 75, or 28·5° F. or 15·8° C. cooler than the mean temperature of the small cylinder walls, 197° F. or 91·7° C. From the weight of the small cylinder, 1·06 lb., its loss in thermal units per minute can be calculated. This amounts to 0·384 thermal units per minute for 0·095 square foot, and is equal to 4 thermal units per square foot per minute, lost by the walls to the condenser. In the above experiment there was very little radiation from the revealer, as it was just above a steam-jacketed and hot cylinder; and also very little conduction of heat along the connecting pipe, which was well covered, as is also the revealer.

Condensation and Fog in the Revealer.—With steam in the jacket no fog is visible, nor can any condensation on the walls be detected by the eye. They are much hotter than the incoming steam. About a quarter of an hour after shutting off the steam in the jacket a little fog is visible, and at the end of thirty-five minutes much fog is seen, and slight condensation on the walls; in other words, as the temperature of the walls was gradually reduced, the amount of fog and condensation increased.

Latest Experiments.—May 1900.

The author has been able to make a few more experiments, with the revealer in all cases open to the low-pressure cylinder of the same steam-engine, and now adds three Tables (pages 520–525) giving details.

All these latest tests have been carried out with a square cast-iron inner cylinder, which replaces the round cylinder shown in Plate 74, and so arranged that it can be either heated by steam, cooled by water, or kept at a constant temperature, and the thermal effects thus studied. The mean temperature of the wall was taken in each case. The Tables hardly require explanation, but the following is a summary of the chief points. When circulating water was used in the jacket the quantity was weighed, and the rise in temperature noted. Indicator diagrams were also taken in each test from the low-pressure cylinder.

Table I. First set. Hot walls cooled down.—Six experiments with different pressures of steam in the jacket of the revealer cylinder, and therefore at different cylinder temperatures. At the start and for some time after, the steam heated the cylinder to a given temperature. It was then shut off and the effects noted every minute, until a constant and minimum temperature was reached, due to the steam from the low-pressure cylinder. The object was to determine the different rates of cooling of the previously heated revealer cylinder. The only condition varied was the temperature of the little cylinder. Comparing column 5 with column 11 it will be seen that in these experiments the walls assume, *not* the mean

temperature of the two strokes (column 13) but nearly that of the *steam stroke only* (column 11). The tests also prove that, notwithstanding the water on both sides of the cast-iron surfaces, their heat-absorbing properties are greater than their heat emission to the exhaust.

Table II. Second set. Cooled walls heated up.—Two experiments were made. At starting, the revealer cylinder was cooled by circulating water to a certain constant temperature; the water was then shut off, and the rise in temperature of the cylinder noted every minute. The object was to determine the different rates of heating the previously cooled cylinder, and also whether the exchanges of heat were affected by more or less water on the cylinder surfaces due to condensation. The temperature of the cylinder only was varied by altering the quantity of circulating water. Comparing tests 1 and 2, about twice as much heat passed in No. 2 per unit of surface, although it had to pass through a greater thickness of water on the walls exposed. This seems to prove that this water does not interfere with the passage of heat through the cast-iron walls, and that the heat absorption goes on notwithstanding it.

Table III. Third set. Constant temperature cylinder walls.—Two experiments were made without shutting off the circulating water. The cylinder was cooled down to the desired temperature, which was then kept constant. One object was to determine whether the heat exchanges would be influenced by more or less condensing water on the external surfaces of the cylinder. Comparing these two tests, about twice as much heat passed in No. 2 from the low-pressure cylinder to the circulating water per unit of surface exposed. It had also to pass first through a greater thickness of water or drops on the surfaces. This seems to prove that this surface-water does not interfere with the passage of heat through the cast-iron cylinder walls, and that the heat-absorption proceeds all the same.

Several of these experiments agree with M. Nadal's theoretical investigations, as published in the "Revue de Mécanique," and with the conclusions he draws, namely, that the heat-absorbing properties of cast-iron are much greater than their heat-emitting properties, and the former are little influenced by the drops or condensation on the steam-engine cylinder walls.

The author has not yet made experiments with surfaces slightly oiled; all the above were carried out with a fairly clean surface. A little oil from the steam cylinder might perhaps have been on them in places, but they appeared quite dry and even a little rusty to the touch. Mr. Martin Smith, to whom he acknowledges his thanks, helped the author in these latter tests. In these experiments the junction pipe from the engine-cylinder to the revealer was very carefully covered.

Radiation Experiments, including the heat lost along the connecting pipe to the Low-pressure Cylinder-cover.—The temperature of the engine-room was 84° to 85° F. The revealer was not open to the low-pressure cylinder. The trial started at 9.8 a.m., with the wall at a temperature of 298°; the steam was then shut off from the revealer jacket. At 3.0 p.m. the temperature had fallen to 105° F., equal to 193° fall in temperature in 368 minutes or 0·525° F. per minute, which is equal to 1·133 lb. × 0·125 (specific heat) × 0·525° F. = 0·074 thermal unit per minute. The loss of heat by radiation of cast-iron cylinder at this rather high temperature of 298° F. includes the heat transmitted along pipe to cylinder cover.

Gain of heat by Revealer cylinder at a lower temperature, some radiation also taking place.—The revealer was on the top, but not open to the low-pressure cylinder, all cocks being shut off. In $7\frac{1}{2}$ hours the revealer cylinder rose in temperature from 94° F. to 100° F. = 6° rise. The temperature of the engine-room also rose from 70° to 78° F. = 8° rise. At these low temperatures the conduction of heat along the connecting pipe is greater than the radiation. The temperature of the cylinder rose with the temperature of the engine-room.

The Paper is accompanied by the following 2 Tables, by Plates 72–75, and 2 Figs. in the letterpress.

TABLE 1.—*Six Experiments on Steam Jacketed Revealer on Factory Compound Steam-Engine—*

With different Pressures of Steam in Jacket to give different Wall Temperatures (Cast
cooling effects. Small Cylinder first heated in all cases to Temperature given in Column 3;
reached. Revealer always open to Low-Pressure Cylinder
Cast-Iron Cylinder with square sides:—Height 2½ in. = 63 mm.; Sides 1·6 in. = 40 mm.
[1*st Series—Hot Walls cooled down.*]

No. of Experiment.	Pressures of Steam in Revealer Jacket, and equivalent Temperatures (by Tables). Lbs. p. sq. in. F.°	Temperatures of Cast-Iron Walls before shutting off Steam in Jacket. F.°	Difference of Temperature of Cols. 3 & 2 due to Throttling of Steam. F.°	After shutting off Steam in Jacket. Time to reach minimum and constant Temperature. min. F.°	Mean Temperature of Walls, beginning and end of Experiment and Drop. F.°	Drop of Temperature of Walls per min. F.°	Heat lost by Walls (weight = 1·133 lbs.) Thermal Units per min.
3	8 = 183°	230°	230° 183° 47°	26 184°	230° 184° 46°	1·77°	1·77 × 1·133 × 0·125 = 0·25
1	18 = 222°	250°	28°	35 185°	65°	1·85°	0·26
2	33½ = 256°	263°	7°	33 184°	79°	2·40°	0·34
4	31½ = 252°	268°	16°	50 176°	92°	1·84°	0·26
5	50½ = 281°	285°	4°	39 180°	105°	2·70°	0·38
6	59¾ = 292°	300°	8°	39 180°	120°	3·07°	0·43
Remarks.	Increasing Pressure and Increasing Temperature.	Increasing Temperature of Walls.	Decreasing Difference with less Throttling (60 lbs. in Boiler).	Minimum Constant Temperature about same in 6 Experiments—Mean 181½°.	Increasing drop of Temperature.	Increasing	Increasing Quantities of Heat for Increasing Wall Temperatures.
1	2	3	4	5	6	7	8

Approximate Temperature of top of Low-Pressure Cylinder cover 162° F. by Experiment
Conclusions, &c.—Comparing Column 5 with Column 11 it will be seen that in these
but nearly that of the Steam Stroke (Column 11). This tends to prove that, notwith-
their heat emission to the Exhaust. Fog and moisture on Walls:—Little or none with
much. Specific Heat of cast iron taken as 0·125 Thermal Units per lb.

(Cylinder with square sides), May 1900, *by* Mr. Bryan Donkin:

Revealer on top of Low-Pressure Cylinder.

Iron) 230° to 300° F., and exposing Walls to Low-Pressure Cylinder (Steam Jacketed) for
Steam then shut off, and cooling effects noted until a constant minimum Temperature was
before and after shutting off Steam in Jacket.
Centre Hole or Jacket 1 in. = 25 mm.; Weight 1·133 lb.; Surface exposed 0·11 sq. ft.

[*1st Series—Hot Walls cooled down.*]

Heat lost by Walls (sq. ft. surface = 0·11 sq. ft.) Thermal Units per sq. ft. per min.	Temperatures from Indicator Diagrams of Pressure taken from Low-Pressure Cylinder at the time.				Difference of Temperature between Cols. 3, 13 & 5, or Cooling Head of Heat. Beginning and End of Experiments. F.°	No. of Experiment.
	Maximum Initial. F.°	Steam Stroke (Mean). F.°	Exhaust Stroke (Mean). F.°	Both Strokes (Mean). F.°		
0·25÷0·11 =2·26	209°	187°	135°	161°	230° 184° 161° 161° 69° 23°	3
2·36	206°	185°	134°	160°	90° 25°	1
3·09	209°	187°	138°	162°	101° 22°	2
2·36	211°	189°	140°	164°	104° 12°	4
3·45	208°	185°	137°	161°	124° 19°	5
3·91	211°	186°	134°	160°	140° 20°	6
Increasing	About same. Mean 6 Experiments = 209°.	About same. Mean 6 Experiments = 186½°.	About same. Mean 6 Experiments = 136°.	About same. Mean 6 Experiments. = 161°.	Much greater difference of Temperature at Commencement of each Experiment than at End.	Remarks.
9	10	11	12	13	14	15

with oil and Thermometer: compare this with Column 13 = 161°, or about same.
Experiments the Walls assume—not the Mean Temperature of the two Strokes (Column 13)—
standing the water on the Cast-Iron Walls, the heat-absorbing properties are greater than
the hotter Walls, but as the Temperature of Walls decreased, both fog and drops increase

TABLE 2 (2nd *Series*).—*Revealer*

Two Experiments with Water-cooled Revealer (Cylinder with square sides), Revealer on Low-pressure Cylinder, and kept always open to it. Water in
water shut off, and

No. of Experiment.	Temperatures of Cylinder cooled to—then water shut off.	Heat gained by circulating water to keep Cylinder at Temperatures given, when open to Low-pressure Cylinder.	After water turned off, time and constant Temperature reached.		Rise of Temperature of Cylinder per min.	Heat gained by the Cylinder.	Heat gained by the Cylinder per sq. ft. of Surface.
	Fahr.°	Thermal Units per min.	min.	Fahr.°	Fahr.°	Thermal Units per min.	Thermal Units per sq. ft. per min.
1	139°	0·4 lb. × 30° rise = 12 T. U. p. m. to keep Cylinder at 139° F.	24	139° 172° 33° rise	1·38°	1·38° × 1·133 lbs. × 0·125 = 0·195	1·74
2	107°	4·12 lbs. × 4° rise = 16·5 T. U. to keep Cylinder at 107° F.	22	107° 172° 65° rise	2·95°	0·418	3·78
Comparisons.	Cylinder at start cooled to Temperature given.	About ten times more water used in No. 2 than in No. 1, and much more heat withdrawn to obtain a lower Temperature 107° F.	About 23 minutes to get a constant hotter Temperature due to Low-pressure Cylinder Steam.		About twice rise in Temperature in latter Experiment.	About twice as much in latter case.	Per Unit of Surface about twice as much.
1	2	3	4		5	6	7

Note.—Column 3, quantity of circulating water weighed and rise of Temperature
Cast-iron Cylinder used 2½ inches long with 1·6 inch width sides, 1-inch hole

Experiments.—Cooled Walls heated up.

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first place allowed to cool Cylinder to a constant Temperature, then heating effects noted.

Temperatures from Indicator Diagrams of Pressures taken from Low-pressure Cylinder at same time.				Remarks and Conclusions.	No. of Experiment.
Maximum Initial. Fahr.°	Steam Stroke (Mean). Fahr.°	Exhaust Stroke (Mean). Fahr.°	Both Strokes (Mean). Fahr.°		
212°	191°	138°	164°	A large amount of condensation on Glass and Cylinder Walls, and with fog at start with colder Walls (139°); much less at end of Test with hotter Walls (172°).	1
212°	188°	138°	163°	Very large amount of condensation on Glass and Cylinder Walls, also fog at beginning of Test with colder Walls (107°); then gradually less at end with hotter Walls (172°).	2
About same in the two Tests. Diagrams like Plate 75.				Comparing Tests 1 and 2, about twice as much heat passed in No. 2 per unit of Surface, although it had to pass through a great thickness of water on Walls exposed. This seems to prove that this water does not interfere with the passage of heat through the Cast-Iron Walls, and that the heat absorption goes on notwithstanding this water.	Comparisons.
8	9	10	11	12	13

taken to get Thermal Units in water. Specific Heat of cast-iron taken as 0·125
in centre, weight 1·333 lbs. External Surface Walls exposed 0·11 square foot.

TABLE 3 (*3rd Series*).—*Revealer Experiments.—*

Two Experiments with Water-cooled Revealer (Cylinder with square sides), Revealer on Low-pressure Cylinder, and kept always open to it. Cylinder constant at Temperatures

No. of Experiment.	Temperatures of Cylinder reduced to (by water). Fahr.°	Quantity of heat gained by the water equals that passing through Cylinder. Thermal Units per min.	Quantity of heat passing per sq. ft. surface. Thermal Units per sq. ft. per min.	Temperatures from Pressures Low-pressure Cylin-	
				Maximum Initial. Fahr.°	Steam Stroke (Mean). Fahr.°
1	140½°	0·38 lb. × 26·1° rise = 9·9 T. U. to keep Cylinder at 140½°.	89	212°	188¼°
2	132½°	1·38 × 16° rise = 22·08 to keep Cylinder at 132½°.	196	213°	191°
10 to 20 minute Experiments. Comparisons.	Fairly constant Temperature maintained by circulating water.	About twice as much heat passing in No. 2 than in No. 1 from Low-pressure Cylinder steam to the water.	About twice as much heat passing per sq. ft. Surface from steam to water.	Tempera Dia	tures rather Experiment grams about
1	2	3	4	5	6

Note.—In this Series the Tests were made without any turning off of the water. Specific heat cast-iron taken as 0·125. Cast-iron Cylinder 2½ inches long with

Cylinder kept at constant and low Temperatures.

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cooled with circulating water to reduce its Temperature, and keep it
given in Column No. 2.

Indicator Diagrams of taken from der at the same time.		Remarks and Conclusions.	No. of Experiment.
Exhaust Stroke (Mean). Fahr.°	Both Strokes (Mean). Fahr.°		
138½°	163°	With much water on the Glass Walls and fog, one could not see well the Metal Walls. All previous Experiments showed that there must have been much water on these Surfaces at such a low Temperature as 140½°.	1
141°	166½°	With much water on the Glass Walls and fog, one could not see well the Metal Walls. All previous Experiments showed that there must have been much water on these Surfaces at such a low Temperature as 132½°.	2
higher in than in No. same as Pla	No. 2 1. te 75.	Comparing these two Tests (1 and 2), about twice as much heat passed in No. 2 from the Low-pressure Cylinder to the circulating water per unit of Surface exposed. It had also to pass through a greater thickness of water and drops on the surfaces. This seems to prove that this surface water does not interfere with the passage of heat through the Cast-Iron Cylinder Walls, and that the heat absorption proceeds all the same.	10 to 20 minute Experiments. Comparisons.
7	8	9	10

Column 3 gives lbs. of circulating water as weighed and its rise of Temperature.
1·6 inch sides, 1-inch hole in centre, weight 1·133 lbs. External Surfaces
0·11 sq. ft.

APPENDIX.

Communication by M. Nadal, *Ingénieur des Mines, France, upon pages* 509–516 *of the Paper.*

The experiments recently made by Mr. Bryan Donkin with his improved revealer throw fresh and important light on various questions touching the phenomena of condensation in steam-engine cylinders.

One of the first points to be considered is, whether that which takes place in the revealer accurately represents similar occurrences in the cylinder. Mr. Donkin is of opinion that "the effects of condensation, as shown by the revealer, may be within 5 to 15 per cent. of the truth."

From this point of view we must distinguish between the three types of revealers:—1st. The original glass revealer without an internal cast-iron cylinder; 2nd. The same instrument with an internal cast-iron hollow cylinder, in contact on all sides with the low-pressure cylinder steam; and 3rd. The latest revealer with a cast-iron cylinder, having only its external surface in contact with the steam from the engine cylinder, while the interior may be heated and cooled at will.

The drops of water, such as are deposited on the walls of the cylinder, are produced by the cooling of the steam against the surfaces with which it comes in contact. In the cooling thus taking place, what part is played by the glass, and what by the cast-iron surfaces? This may be approximately determined beforehand. Heat is much less easily propagated through glass than through cast-iron, because the coefficient of internal conductibility of glass is about eighty-two times less than that of cast-iron. On the other hand, the calorific capacity of glass is greater than that of iron, in fact almost double. Taking these circumstances into consideration,* we find that a cast-iron wall ought to absorb at least six times more heat than a glass wall. Consequently, the effects of condensation seen in the revealer of the original type, which was wholly of glass, would be at least six times less marked than in the cylinder of the engine, if these effects were due only to the action of the walls of the revealer themselves. But this is not the case. If it were, the revealer would always show the same results for the same cycle of steam, whether the steam-engine cylinder were jacketed or unjacketed. As this is not so, it follows that the greater part of the drops seen in the revealer —of the original or first type—are not due to the cooling of the glass, but have been simply carried in with the steam, and precipitated on to the glass. We may even assume that the drops, as well as the fog, are almost entirely owing to the cooling caused by the junction pipe uniting the revealer to the cylinder when this pipe is not covered, as its internal surface is relatively large.

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* Revue de Mécanique, December 1898. "Principes de la Théorie Mathématique de la Machine à Vapeur."

Mr. Donkin has, in fact, brought out in his experiments the great influence this connecting pipe has on the condensation, and has verified the following phenomena:—By artificially cooling the short iron connecting pipe between the revealer and the cylinder, with cold water and a sponge, the fog or cloud on admission of the steam at the commencement of the steam stroke is much increased, as is also the diameter of the globules on the internal glass walls. The steam seems to be chilled. Two other revealers, with single glasses, and longer and uncovered connecting pipes fixed on to the same end of the same low-pressure cylinder, gave during the same stroke greater condensation effects and larger globules, with more fog.

In this latter case the action of the glass itself in producing the moisture is very small. The drops seen on the glass have been carried in and flung against it by the current of steam previously formed elsewhere, principally, perhaps entirely, in the uncovered junction pipe.

This view is confirmed by Mr. Donkin's experiments made in December 1899, on the third type of his revealer, Plate 74. When the latter is fixed to the low-pressure cylinder of a compound engine, and steam from the boiler is admitted into the little cast-iron central cylinder, so that it is jacketed in exactly the same way as an engine cylinder, neither fog nor condensation are seen. Now the glass cylinder is not jacketed, but simply protected from external cooling, and its action is always the same in all experiments; the absence of condensation and fog in the above case effectively proves that of itself it has no marked action on the effects of condensation. On the other hand, surfaces of the motor (steam-engine) piston in these experiments act like an unjacketed wall, and must therefore cause a certain amount of steam to condense on them. As this separate condensation is not shown in the revealer, it confirms the opinion that when moisture and drops of water are seen in the latter, they come only from the cooling of the steam in the connecting pipe. When live steam from the boiler is admitted into the little revealer cylinder, the junction pipe of the low-pressure cylinder is heated by condensation at either end, and as it is at a higher temperature than that of the steam inside, it does not give rise to any condensation.

The foregoing considerations show that the phenomena taking place and seen in the revealer, depend mainly on the arrangements and covering of the connecting pipe.

In the *second type* of revealer the little hollow cast-iron cylinder surfaces act like the surfaces of a non-jacketed wall; in other words, like a motor piston or like the little inner cylinder of the third type of revealer when steam is not admitted to it.

The trial made in December 1899 on the *third type*, Plate 74, shows very clearly that what takes place in the revealer does not always correspond with the phenomena in the engine cylinder. In this experiment live steam from the boiler is first admitted into the little cylinder of the revealer, then shut off. Its mean temperature in the small cylinder is 299° F. or 148° C. at admission; it then falls, and at the end of thirty-five minutes it becomes stationary and equal to 197° F. or 92° C. In the first case (with the steam at the higher temperature) the little cylinder affects condensation like the jacketed cover of a steam-engine cylinder, and since neither condensation nor fog are seen in the revealer, this proves that the jacketed walls of the steam cylinder, being much hotter than the working steam, cause no condensation. In the second case (when the temperature of the steam has fallen) the surface of the little cylinder acts like the motor-piston surfaces, which are not heated, and as the latter cause condensation of the steam, we get the corresponding effect of much fog and slight condensation in the revealer. In the one case, as in the other, the phenomena of condensation in the steam cylinder, taken as a whole, have not varied. In the first, the revealer does not show what is occurring in the cylinder; in the second, it shows it with almost perfect accuracy.

Summary.—To summarize the matter, the improved revealer has an action of its own, which represents or does not represent the phenomena produced on the steam cylinder surfaces according to whether the little cylinder is or is not placed in the same conditions as the walls of the steam cylinder. The influence of the connecting pipe may sometimes cause the indications of the revealer to vary considerably from the phenomena actually taking place in the motor cylinder. But in any case these indications are of great interest, and we may now study the precautions necessary to make them wholly conform to reality.

Temperature of Walls in Type 3.—In the experiment of December 1899, after the admission of live steam to the little cast-iron cylinder of the revealer had been shut off, the mean temperature of this cylinder, after a certain time, became stationary, and ought to represent the temperature at which the walls of the steam cylinder would be, if the admission of live steam to the jacket were arrested. The mean temperature of the little unjacketed cylinder is hotter than the temperature shown by the diagram, 197° F. − 168·4° F. = 28·5° F. This conclusion perfectly agrees with the results formerly obtained by Mr. Donkin,* results which led the writer, by applying to them the equations of the propagation of heat, to draw up a formula giving the mean temperature of unjacketed walls. For a condensing engine this formula is as follows †:—

$$t_o - v = 0{\cdot}42\,(t_o - t_d) + 0{\cdot}08\,(t_o - t)$$

in which t_o is the maximum temperature of the indicator diagram,

t_d „ temperature at the end of expansion,

t_e „ minimum temperature of the diagram,

v „ mean temperature of the metal wall.

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* Proceedings 1895, page 90.

† Revue de Mécanique, May 1899 and Feb. 1900. "Théorie Mathématique de la Machine à Vapeur."

These temperatures may be expressed in either Fahrenheit or Centigrade degrees, without altering the coefficients of the formula. In the trial in December 1899, t_o was $= 220°$ F., $t_d = 175°$ F., $t_e = 135°$ F. Applying the formula we get $v = 194 \cdot 3°$ F.; while the thermometer marking the mean stationary temperature of the little unjacketed cylinder gave 197° F. These two figures sufficiently agree, although the first is a little lower than the second, and confirm Mr. Donkin's former experiments in a satisfactory manner.

It might be supposed, that if the stationary temperature of the little cylinder is higher than the mean temperature from the diagram, the difference is due to the heating of the revealer by radiation and conduction along the connecting pipe, the revealer being placed at the top and close to the cover of the steam cylinder. Such heating does actually take place, but we have reason to believe it is not of much importance. It may, however, serve to explain why the value for v found by experiment (197° F.) is slightly higher than that deduced from theory (194·3° F.). To determine accurately the influence of this heating we have only to cut off the admission of live steam to the jacket of the little revealer cylinder, and to that of the steam cylinder. The resulting fall in the temperature (v) would show the effect of radiation and conduction. The knowledge thus gained would be confirmed if it were possible, at the same time, to take the mean temperature of the unjacketed cover of the steam cylinder. [These latter temperatures have since been taken.]

To obtain the Temperature of the Cylinder Walls.—Lastly the improved revealer (type 3) can easily be used to determine the mean temperature of the unjacketed walls, without the necessity of boring holes in the walls of the motor cylinder itself.

The experiments of December 1899 also yield very interesting conclusions with respect to the greater or less ease with which the heat penetrates or is given out by the cast-iron metal surfaces. As soon as the little cylinder was no longer heated internally, its mean temperature fell 102° F. in thirty-five minutes, or about 2·9° F. or

1·6° C. per minute. From this Mr. Donkin deduces the corresponding flow of heat. The weight of the little revealer cylinder being 1·06 lbs. the loss of heat (taking 0·113 as the specific heat of cast-iron) is 0·08895 calorie per minute, and, the external surface of this cylinder being 0·095 square foot, the flow of heat is 3·72 T.U. per square foot per minute (or 0·17 calorie per square mètre per second).

If the steam be again admitted to the jacket of the little cylinder, the mean temperature of the latter rises from 197° F. to 285° F. in about a minute (92° C. to 140° C.). The amount of heat which penetrates from the interior surface of the cylinder is therefore 2·668 calories per minute, this surface being 0·00487 square mètre in extent. Thus the flow of heat increases to 547 calories per square mètre per minute, or 9·11 calories per second, and is fifty-four times greater than the flow of heat given out by the external surface of the cylinder, as above calculated. This shows the extraordinary rapidity with which the heat passes from the jacket steam into the cylinder metal, while, on the other hand, it is given out slowly and with difficulty from a dry metallic surface in contact with steam colder than itself.

We may especially notice from Plate 75 that, in the interval from half to three-quarters of a minute after the live steam had been readmitted to the little cylinder, the temperature of the latter rose from 240° F. to 270° F., that is, 30° F. or 16·65° C. Hence we may conclude that during this interval the flow of heat rose to 12·3 calories per square mètre per second. From the theoretical equations of the propagation of heat, we can calculate what would be the flow of heat per square mètre per second per degree Centigrade difference in temperature between the steam and the metal surface in contact with it; in other words, the coefficient called the "absorbing power." If this be calculated in terms of the equations given above, it should be 36 calories [in English units: 7·38 T.U. per square foot per second per degree Fahr.]. The mean difference between the temperature of the steam and that of the metallic surface during the interval we are now considering is 0·34° C.

Thus while the absorbing power of the wet metallic surface is 36 calories, the emitting power of the dry metallic surface, calculated in the same way, is only about 0·1 calorie. This result tends again to justify the opinion put forth by the writer in his "Théorie Mathématique de la Machine à Vapeur," and to close the discussion lately started between Professor Anspach and himself respecting the possible maximum value of the "absorbing power."

Discussion.

Mr. Bryan Donkin said it might perhaps help the discussion if he indicated that three different forms of revealers were shown on the table. There should be a cock at the bottom near the flange of any revealer to shut it off from the cylinder. The Members would notice the position of the revealer on a horizontal cylinder engine, Fig. 1 (page 510), and also the application to the vertical cylinders, Fig. 2 (page 511). There was one important point in using revealers, namely, that they must be heated up. They had often been used, but when put on a cylinder cold, naturally the glasses broke. He would also like to direct the Members' attention to a Paper on the "Transmission of Heat from Surface Condensation through Metal Cylinders," written by Lieut.-Colonel English and himself some years ago,* dealing with the question of transmission of heat from steam to water. Of course the condensation effects were quite different, as would be seen by the drawings of drops in the Papers. The drops in the revealer were hemispherical, as shown in Plate 72. Perhaps some explanation was due from him for devoting the attention of the Institution of Mechanical Engineers to such a small apparatus, but a very learned Paper was once read with the title "Next to Nothing." It was open to anyone to make a revealer from the drawings given; it was perfectly simple to construct, the only important provision needed being, as he had mentioned, that it should be heated up for an hour or more before use by putting it on a hot cylinder. Another important point was to have the connections large, direct, and without bends—that is to say, the connecting pipe between the steam cylinder and the revealer should be short, direct, and well covered. In the older forms the pipes were rather too small. He would be glad to receive suggestions from any members with the view of improving the apparatus. With regard to photographing the drops, that had been attempted by several people. He had made many attempts without much success. It was extremely difficult to do well. A very strong light was required, as the condensation and re-evaporation were very rapid. It would be interesting if the temperature of the drops could be determined electrically, but it was a difficult problem. Of course they took up a certain temperature, probably somewhere between the temperature of the cast-iron wall on which they were formed, and that of the steam behind them. Another point about which some of the Professors could perhaps give additional information was why the condensation drops were hemispherical in form.

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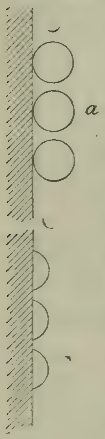
* Proceedings 1896, page 501.

Professor W. Cawthorne Unwin, Honorary Member, thought it must be eight or ten years ago since Mr. Donkin invited him to Bermondsey to see the first revealer on a steam-engine cylinder. That first apparatus showed very clearly indeed two things which, he supposed, had not actually been seen before, though they all knew of them: first, that there was condensation on any solid surface exposed to the steam, a condensation which increased during one part of the stroke and then re-evaporated. It also showed another thing. It showed very clearly the fog in the steam, which he supposed must have been adiabatic fog due to condensation, in consequence of work being done by the steam. Since that time Mr. Donkin had expended an immense amount of admirable ingenuity in making the conditions of the apparatus approximate inside the cylinder itself. The author said in the Paper (page 510) that the apparatus perhaps represented the actual conditions of the

(Professor W. Cawthorne Unwin.)

inside of the cylinder walls with an accuracy within 5 to 15 per cent. He was afraid that that, after all, was very much a guess. He confessed he would rather lean to the opinion that the apparatus was qualitative and not quantitative, and that they could not make any statement as to its showing the conditions inside the wall with an accuracy of any particular amount. As a qualitative apparatus it was no doubt interesting. Doubtless there was some correspondence, as the auther had shown, between the phenomena which went on in the cylinder and in the revealer, and there was a certain visible increase of condensation in certain conditions, and a decrease in others. On one point he would like to say a word. He supposed that anyone who had studied the theory of the steam-engine knew that many years ago a controversy arose amongst students of thermo-dynamics, especially Zeuner and Hirn, so that there existed two schools of opinion as to the relative part taken in the action of the cylinder walls by the metal of the walls themselves and by the water eposited on them, a controversy which was summed up in the phrase, "Is it iron or is it water?" There was a phrase in the Paper which rather lent itself, he thought, to a misinterpretation, as having a bearing on that controversy. The author made a point of having demonstrated that the condensation on the cylinder wall consisted of drops, Plate 72, and not of a film, as he said had been very generally supposed (page 514). He thought that lent itself to a misconception. Fig. 3 at *a* showed a section of a cylinder-wall with what would strictly be drops adhering to it. Such drops would touch the wall only at a point, and the wall itself would be dry. If that were the mode of condensation, there would be very little exchange of heat with the metal wall. Only the water drops would take part in the heat exchange. But really what the author had shown was what was indicated in Fig. 3 at *b*. The "drops" adhered to the wall by a large surface, and heat exchange would go on through this surface between the water and metal. The really accurate statement about the observations, he thought therefore, was not that instead of the film

Fig. 3.



on the wall there were drops, but instead of a continuous film on the wall there were patches of film, and those patches of film behaved altogether like a continuous film. It was interesting to know that there might be dry patches in a cylinder wall on which large condensation was taking place, but the action, he imagined, was exactly that of a continuous film. There was one other point which, he thought, lent itself a little to misinterpretation. He did not quite understand what the author thought he had discovered as to the relative heat-emitting and heat-absorbing properties of the wall, but what he said seemed ambiguous. In an experiment, in which the cylinder-wall appeared to have been more or less continuously wet, he asserted that the heat-absorbing capability of the wall was greater than its heat-emitting capability. In M. Nadal's Appendix (page 532) there was a different statement, namely, that while the absorbing power of a wet metallic surface was 36 calories, the emitting power of a dry metallic surface was only 0·1 calorie. That a wet surface exchanged heat immensely more readily than a dry surface had been for a long time perfectly well known, and was a fact which was taken into account and insisted on in every theory of cylinder condensation. M. Nadal's statement was therefore what was perfectly well known, but he doubted whether the heat-absorbing and heat-emitting properties of the wet wall differed in that remarkable way. For what would it mean? If that statement applied to what went on in an actual steam-cylinder, that is, if the wall of the cylinder absorbed more heat than it emitted, it must be very rapidly getting red hot, because the heat quantities they had to deal with were very big indeed, and one had to give some explanation where the heat went to if the wall was absorbing more than it emitted. There must be a balance between the absorption and the emission, except so far as there was a definite small outward flow of heat due to radiation in the case of an unjacketed cylinder, and a flow into the cylinder in the case of a jacketed one.

Mr. J. Macfarlane Gray said that in Plate 72, in the left-hand bottom corner, there was a very interesting picture of large drops with smaller drops very regularly placed at intervals. He would

(Mr. J. Macfarlane Gray.)

like to ask if that was what was seen; was it an *actual* or was it an *ideal* picture?

Mr. Donkin said it was a representation of what was seen from sketches made during the experiments. There was no oil on the surfaces.

Professor David S. Capper wished to express the extreme admiration he felt for the ingenuity and devoted labour which the author had expended upon experiments on revealers for some years past. The information thus obtained, as Professor Unwin had pointed out (page 534), had been extremely interesting from a qualitative point of view. It was the quantitative deductions, which the author drew from these experiments, to which one perhaps had tentatively to take exception. It struck him that possibly there might be some connection between the broken nature of the water films on the cylinder-walls noted by the author, as modified by Professor Unwin, and the fact that the cylinder-walls, after the experiments were over, seemed to have patches of oil upon them in some places and to be dry in others. It seemed to him that the dry portions of the cylinder might have coincided with the positions of the drops as seen by the author. It would be interesting to know if the author had noticed such a connection or not. The point to which he would like to draw most attention was the deduction drawn by the author from the experiments of May 1900, as given on page 517, particularly with reference to Table 1. The author said (page 517) that comparing column 5 with column 11 of the Table the walls assumed not the mean temperature of the two strokes, but nearly that of the steam-stroke only, and went on to say "the tests also prove that, notwithstanding the water on both sides of the cast-iron surfaces, their heat-absorbing properties are greater than their heat emission to the exhaust." The way in which the temperatures were taken, from which those deductions were drawn, was by means of a thermometer, which was figured in the Paper as one-eighth of an inch in diameter. Consequently, as they knew that the transmission of heat was due to the thermal gradient from one side to the other of a definite thickness of cast-iron, if the conditions were steady there would be a steady gradient. It was evident that if that gradient were steep, the thermometer was not taking the temperature of one point on the gradient, but the mean of a considerable number of points at the higher portion of the gradient. Therefore the temperature, which was read from that thermometer, was not the temperature of one point on the surface of the metal, but was the mean of a certain number of temperatures higher up the gradient. Consequently it seemed to him that the deduction which the author drew was not borne out by the manner in which the experiment was made; because it seemed that the actual observed temperatures corresponded very closely to what one would have expected to find in the inside of the metal of the cylinder. The steam was admitted through the internal pipe, was then shut off, and the effect noted, until it was found that a steady and constant reading of the thermometer was obtained. That meant that a steady gradient was set up, or a gradient which was steady for a considerable portion of its length, and consequently the thermometer would not take the temperature of the outside wall where the cylinder steam was, but it would take up a temperature which was somewhere between that temperature and that of the internal cylinder where the steam-pipe was. One would therefore conclude that the temperature shown on the thermometer would certainly be above the mean temperature of the two portions of the stroke in the cylinder.

Again, with regard to the second set of experiments as instanced in Table 2, the author pointed out (page 518) that "comparing tests 1 and 2, about twice as much heat passed in No. 2 per unit of surface, although it had to pass through a greater thickness of water on the walls exposed." It seemed to him that the evident cause of that was, that in the one case there was twice the gradient that there was in the other, and consequently to his mind it did not confirm the conclusion that the experiments seemed to prove that the water did not interfere with the passage of heat through cast-iron walls. The result seemed to him to be more probably caused by the steepness of the heat gradient, and there was

(Professor David S. Capper.)

therefore no proof that the interposition of the water on the walls had no effect. In criticising a Paper of that description, one naturally had to bring forward the points which caused difficulties in one's own mind, and therefore in making criticisms of that nature he knew that the author would understand, that he did not in the least lessen his extreme admiration for the manner in which the experiments had been carried out.

Mr. Henry M. Rounthwaite said that as a practical engine-builder he had been scrutinising the Paper, with a view to seeing whether he could derive from it any hints that would assist him in his daily work. He believed that most engineers had an idea that something of the sort described in the Paper occurred in steam-cylinders, but they had now to thank the author for having lifted it out of the region of supposition and into that of fact. It appeared to be clear from the author's experiments that, by heating the walls of the cylinder sufficiently, condensation on them could practically be got rid of altogether. But the question then arose, would this be desirable or advisable? Would steam-engines work satisfactorily under those conditions? He believed there was a considerable body of evidence tending to show that they would not. It had been found recently that, where unusually high jacket temperatures had been applied, trouble from cutting of cylinders had arisen, not only in engines working with very high-pressure steam, but in those working with what was now considered quite moderate pressures, and not only in high-pressure cylinders, but in the low-pressure cylinders. A very good example of this trouble was given by the tail rods of inverted marine-engines. All marine engineers knew that the glands on the cylinder-covers, through which these rods passed, gave a great deal more trouble than the main glands below, and this in spite of the fact that the upper ones were much more favourably situated for oil lubrication. He would be glad to know whether Mr. Donkin had considered this view of the question, and whether he had made any experiments which would throw light upon it; or whether any of the members present could give any information on the point. It almost appeared that a further series of experiments was required before engineers could decide whether, or how far, they could act on the information which the author had so unreservedly placed at their service. He would also like to ask whether the dimensions of the cylinders were correctly stated in the Paper (page 509), as the ratio was about 33 to 1, and the low-pressure diagram scarcely seemed to give evidence of such an unusually large ratio.

Sir Frederick Bramwell, Bart., Past-President, said he did not remember whether, on a previous occasion when the subject was before the Institution, reference was made to an experiment that was carried out by Mr. E. A. Cowper and Sir William Siemens, but on the occasion of a Paper by the President, Mr. John Penn, in 1859, on "Superheated Steam in Marine Engines," * Mr. Cowper said (page 204) "he had tried a direct experiment suggested to him by Mr. Appold, namely, fixing a glass gauge tube in communication with the interior of the cylinder, the outer end of the tube being closed: at the beginning of the stroke the interior of the glass became quite dull with moisture, from condensation going on in the cylinder; but towards the end of the stroke the moisture was entirely evaporated and the glass became clear, showing that there was perfectly dry steam in the cylinder by that time. The cylinder was in fact a partial condenser at the beginning of the stroke, and a boiler at the end of the stroke; and if it were not for this boiling off of the condensed water at the end of the stroke, the cylinder would soon get very nearly to the temperature of the steam."

Mr. Henry Davey, Member of Council, said he was sure the author's reputation as a careful experimentalist required no support from him, but he could not help looking at the Paper from the point of view which it had been looked at by Professor Unwin and others, namely, that it was an exceedingly valuable contribution to the Proceedings of the Institution, as a qualitative Paper, but when the quantitative results were considered he thought they were open to criticism. When one came to look carefully into the small

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* Proceedings, 1859, page 195.

(Mr. Henry Davey.)

apparatus, and all the conditions which were necessary for carrying out the experiments with it, it would be seen how very liable to error it might be, because there were so many disturbing influences. What he wished to direct attention to was the statement in the Paper which had been criticised by Professor Unwin and also by Professor Capper, namely, that the heat-absorbing properties of cast-iron had been shown by the experiments to be greater than the heat-emitting properties. He noticed an interesting formula constructed by M. Nadal was given to express the difference. Before the meeting, the author had informed him that the formula was constructed on the results of experiments which he had carried out himself much on the same lines on a steam-engine. It struck him that, although the observations in the revealer which tended to show this result might have been quite accurate, the deductions were subject to an error which he did not think had been taken into account. It was an error quite different from any of the others which had been pointed out by the previous speakers. The author found that the mean temperature during the steam-stroke did not coincide with the mean temperature of the diagram. If he had a cold substance, and had also a hot one, and he applied them alternately for equal times to a third, and that the operation was continued very rapidly, one would expect that as the times of application were the same, that after a certain number of very quick applications the third substance would assume something like a mean temperature between the two temperature applications. In that case however he assumed that the times had been the same. He did not think the times had been the same in the author's experiment. If he plotted a temperature-curve above the steam diagram, he would get a curve; and the mean temperature of the curve would not be in the middle of the stroke, but nearer the end. Therefore the higher temperatures had been in contact with the metal to be heated for a longer time than the lower temperatures had, so that there would be a greater heating effect from that fact alone. He gathered that the formula, which was given in M. Nadal's Appendix (page 529), had been deduced from experimental results, which might have been subject to this error. He might say, without betraying any confidence at all, that Professor Hudson Beare, of University College, had had in hand for a long time some experiments on the condensation of steam, which were conducted in a somewhat analogous manner to those of the author. Professor Beare found there were so many disturbing influences, variations in the quality of the steam, the conducting effects from the connections, the difficulty of keeping the time of admission constant, &c., that he had very great difficulty in getting consistent quantitative results. This had delayed for a long time the completion of his experiments. He mentioned that to show what difficulties had been encountered. He was sure there was no one more willing than the author himself to acknowledge that there were very potent and difficult disturbing influences always at work in attempting to get quantitative results from that apparatus.

Mr. William Schönheyder said he would like to make a suggestion to the author as to a slight addition to his apparatus, which would show more accurately what went on inside the cylinder than it did at present. The walls of the cast-iron internal cylinder in the small apparatus had no piston passing over it, and there was no oil on it. It would be a very simple matter to add to the apparatus a moving piston, which would flatten down the globules of water on the cylinder, and perhaps alter the rate of condensation. A drop of oil could also be added now and then, and the effects observed. The way in which that could be done was very simple, and the piston could be worked at the same rate as the main piston of the engine. He did not know whether the author had thought of this.

Professor Robert H. Smith said he had always thought that what was revealed by Mr. Donkin's revealer was a very interesting ocular demonstration of what they had for long been accustomed to believe took place in the steam cylinder, and what they imagined had been proved by other means to take place. Much had been said as to the difference between its qualitative and its quantitative merits. He thought there were only two quantitative assertions made

(Professor Robert H. Smith.)

by the author in his Paper. The first was that the results indicated were within 5 to 15 per cent. of what actually occurred inside the working cylinder (page 510). He did not suppose that the author put that forward as anything but a pure guess. For his part he thought that, although perhaps the results might be within that percentage of approximation, certainly the general conditions inside the revealer were not within 5 or 15 per cent. of those effective and influential conditions which existed inside the cylinder. The other quantitative results referred to were those put down in the Tables obtained from his later experiments (pages 520–5). Those, he understood, were all obtained from the small thermometer inserted in the inside metal wall of one form of the instrument. That was not an essential part of the revealer: it was not a part of the original revealer at all. The thermometer indicated the average temperature a little way from the surface of the metal wall, and did not pretend to show the changes of temperature at the actual metal surface or in the steam itself. The results agreed practically with those obtained by Professor Callendar, and they also agreed with the result which he thought was now generally accepted from the direct measurement of condensation in steam-engines, namely, that the condensation in the cylinder depended upon the difference between the initial and final temperatures on the expansion-curve, and did not depend on the temperature of the exhaust-line. The author said that those observations proved that there could not be any thin film of condensation water on the surface of the steam-engine cylinder. He could not understand that, because all the experiments showed that the cylinder became covered with drops of water which were practically a film of water, as Professor Unwin had pointed out (page 534), during at least a large portion of the time of the revolution; and surely that covering of drops of water must be influential in the whole phenomenon. If the author meant, that his instrument showed that during the exhaust period there was no film nor any influential degree of wetness upon the surface of the metal walls, and that therefore on the admission of the next portion of steam, that steam found the walls practically dry, his observations tended so far to prove the correctness of this inference, but they covered only a rather small range of condition. He thought the influential conditions in the revealer were extremely different from those that existed inside the working cylinder. He did not like the mixture of glass and iron, which did not exist at all in the working cylinder, and which must make an immense difference in the results. He would like to suggest that the glass was not necessary, and that the connecting pipe was not necessary. He fancied that a small circular recess fashioned in the cover of the cylinder, and wholly made of metal, except for two small holes, one for throwing in a strong beam of light, and the other for the application of the observing microscope, would be a better form of the instrument and would do away with all glass except those two small windows. The phenomenon of which the revealer helped the investigation was complicated, because of the admixture of three different phenomena. First there was the change of pressure, which was diffused almost instantaneously throughout a large compound mass of steam and water. There was then the change of temperature, which was a very different thing. Change of temperature did not get diffused through a mass of fluid with anything like the same rapidity. Part of it took place very slowly indeed. So far as it depended upon simple change of pressure, he believed it did diffuse very rapidly throughout a mass of expanding gas and steam. But in so far as it depended upon conduction of heat, it took place slowly. A change of temperature distributed itself through a mass of water very slowly indeed. It was extremely difficult to mix up masses of water that were getting heated, so as to obtain anything like a uniform temperature throughout the mass. Along with the expanding steam there was always a large amount of water, and it seemed improbable that the temperature of the water should change in the same rapid way that the temperature of the steam did. Again, there was a third phenomenon going on, namely, the diffusion of the water throughout the mixed mass of steam and water, and that took place according to another law altogether. Under some circumstances that water might diffuse as cloud throughout the whole mass very quickly, and under other circumstances and in other situations it might get diffused very slowly indeed. There was a big mass of

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water gathered upon the solid walls, and a very much smaller mass of water diffused in the shape of cloud throughout the steam space.

Mr. Donkin was very glad to hear Professor Unwin's remarks (page 534), but as far as his own observations went, the drops were hemispherical in shape. He quite agreed with Professor Capper's remarks (page 537), that only a mean temperature of the wall was obtained. He was also quite aware that it had been demonstrated in many other Papers, that a surface temperature of about ½ mm. thick was constantly varying in temperature during a stroke. The mean temperature of the cast-iron wall in these experiments was obtained.

With regard to Mr. Davey's question (page 540) as to the mean temperature of the indicator diagram, it was not taken as Mr. Davey supposed. He divided the diagram into ten equal parts on a time base, and the average temperature of the steam-stroke was thus accurately obtained. In reply to Mr. Schönheyder's suggestion (page 541) that a piston should be used, that had already been tried, but unfortunately it was of no use, as the condensation took place much faster than the piston could be worked. In some experiments * which were conducted by Lieut.-Colonel English and himself, a piston was used. It was worked first up and down by hand, and then by the engine, but the condensation was much too rapid, and it was found quite useless.

In regard to what Professor Smith had said (page 543), he was afraid if he bored a hole in the cylinder, and fixed a piece of glass in, he would see nothing at all. There would be so much oil and water, and so little light, that he would get no results. There must be some sort of prolongation of the steam-cylinder. He was glad that such criticism had been made, and to see that the subject had been of some interest to the Meeting.

The President thought the members would agree that they had listened to a most interesting Paper and discussion, and the

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* Proceedings, 1896, page 501.

Institution's best thanks were due to the author for giving another example of his excellent experimental work. It might be qualitative rather than quantitative, but he was sure they were all agreed, that in Mr. Donkin's hands they were getting as much information in that direction as they were likely to get. He had noticed that whenever the speakers had made a suggestion for a further experiment, Mr. Donkin had always been able to reply immediately that he had tried it, and had found the present a better plan of experiment. He hoped Mr. Donkin would come before them on many future occasions and give them the result of his valuable work.

Communications.

Mr. T. W. Barber wrote that, in carrying out experiments of this nature, the accuracy of the results would be much vitiated if direct tests of the condition of the steam before admission to the engine cylinder were not simultaneously made. The indicator diagram was useful to that end, but not sufficiently reliable. It would be interesting to know if the author had made any such tests. The conclusions drawn from these experiments were founded upon the assumption which was expressed in the following words (page 514): "It is now generally admitted that condensation of steam in engine cylinders is caused chiefly by the difference of temperature between the internal surfaces and the steam in contact with them." In the opinion of the writer this was an erroneous assumption, and was not borne out by the results obtained from the revealer. The low-pressure cylinder under consideration was jacketed, and the jacket steam, at a pressure of 60 lbs. per square inch, would keep the cylinder wall at a temperature somewhere about 290° F. The steam in the cylinder had an initial temperature of about 220° F., and an average temperature on the forward stroke of 193° F. (it was lower on the return stroke). Under what circumstances was it possible for steam at these low temperatures to condense by being brought into

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contact with a surface constantly heated up to 290° F.? The piston and covers might be unjacketed, but even should some condensation take place on them, it would not affect the cylinder wall. In the high-pressure cylinder the same conditions prevailed, but to a less degree; in either case, however, the wall was hotter than the incoming steam.

The tests showed that a distinct fog appeared throughout the steam space. This again was not in accordance with a surface-condensation theory, since only that steam near the cylinder wall and ends could possibly be affected by contact with them. The reason for the fog throughout the steam must be sought for elsewhere.

Again, in the revealer the size of the globules of condensed steam were the same on both the glass and iron surfaces. If these globules were due to direct condensation on those surfaces this uniformity would not exist, owing to the very great difference between the heat capacities of glass and iron. M. Nadal attributes this uniformity to condensation taking place in the junction pipe and the drops being carried through into the revealer. The author says (p. 519) "in these experiments the junction pipe from the engine-cylinder to the revealer was very carefully covered." This being the case, it was not at all likely that more condensation would take place in the carefully covered pipe than in the partially exposed revealer. The radiation of heat from a well lagged cylinder was, compared with the amount of heat which disappeared within the cylinder, a small quantity, and condensing effects from this cause must also be equally insignificant.

In an engine-cylinder (as elsewhere) steam was condensed, or, to use a better term, *devaporised* when it performed work or parted with a portion of its energy. Excluding questions arising out of the energy lost in the exhaust, the work performed in the cylinder might be classified as:—

(*a*) Energy expended in expansion of volume.

(*b*) Energy lost by radiation through the cylinder wall and ends.

(*c*) Energy transmitted to the piston.

(*a*) It was generally supposed that steam lost no energy when it merely expanded. Experiments made by the writer have led him to a different conclusion. Energy was lost whenever the condition, inertia, or state of equilibrium of the steam was disturbed, and *devaporation* to a corresponding extent was the accompanying result. Combined temperature and pressure tests, such as indicator tests, did not give an absolute index of the amount of energy contained in steam.

(*b*) The amount of energy lost through the cylinder wall and ends by radiation varied with the circumstances of the case. Under ordinary conditions with good lagging it was small; where steam jacketing was used, it was probable that *more* energy was absorbed, through the wall by the steam than was lost through the piston and ends, so that there might be an actual *gain*.

(*c*) By far the greater portion of the utilised energy was transmitted to the piston.

Devaporation throughout the volume of steam was caused by items (*a*) and (*c*). Local *devaporation* by item (*b*). Since (*a*) and (*b*) were comparatively small factors, (*a*) being negligible and (*b*) only of account in uncovered and exposed cylinders, it was clear that *devaporation* must be largely due to (*c*).

When the steam entered the cylinder it met with a sudden check to its progress, the piston being practically motionless, its inertia was disturbed and its energy was expended at a comparatively rapid rate upon the piston, wall, and end. *Devaporation* took place throughout the volume, and the fog thus caused was observed in the revealer. As the piston accelerated and the steam expanded, a less demand was made upon its store of energy, and a condition approximating to a state of equilibrium once more prevailed. *Devaporation* correspondingly decreased. It was also probable that the steam so far recovered, as it were, from the first shock on admission that an appreciable portion of the moisture was re-evaporated and absorbed into its volume again. A portion of the energy momentarily absorbed by the walls would assist this, and, in the case of a jacketed cylinder, a still further evaporating effect would be available to accelerate and accentuate this process.

The revealer showed that in the high-pressure cylinder more *devaporation* took place. This was to be expected, since the

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conditions predicated a much greater disturbance of inertia at the beginning of the stroke, and a proportionately larger absorption of energy for the time being. When the revealer was used with the centre chamber heated or cooled independently, its results were probably unreliable, because it was so constructed that all the steam entering must impinge upon the heated or cooled chamber, and the condition of this steam must be modified accordingly. It was only when the temperature of the whole revealer was approximately that of the steam—*not of the cylinder walls*—that the character of the entering vapour would not be largely modified.

The attempt to imitate the condition of the cylinder wall and ends in the revealer, arose from the assumption that condensation was largely due to their influence. It was doubtful if such an attempt on the lines described could be successful, and in any case it was based, in the writer's opinion, on a misconception and was unnecessary. What was required was simply a receptacle which would not modify the entering steam to any appreciable degree. Some modification was inevitable, whatever means were used, but the writer thought that, comparing the results with those he had obtained under different circumstances, Mr. Donkin was not setting too high a percentage on their value, when the conditions described in the first two experiments were observed.

Professor T. Hudson Beare wrote that he wished to put on record his appreciation of the extreme ingenuity shown by the author in the various improvements he had made in the glass revealers. In the latest type of the apparatus, shown in Plate 74, the author had designed a piece of apparatus which no doubt showed in a qualitative manner what went on inside the cylinder of an engine and the influence of the jackets on initial condensation in the cylinder. He was afraid, however, that it was not possible to obtain definite quantitative results from these experiments, though he quite appreciated the remarks communicated by M. Nadal on the figures obtained by the author in his experiments. M. Nadal pointed out that the glass revealer only represented the actual phenomena in the steam-cylinder when under certain conditions, and that the influence of the connecting pipe, etc., might be very great. The writer thought that this point was brought out very clearly by the statement of the author, that (in the experiments of Table 1, pages 520–1) no fog was visible in the glass cylinder until the temperature of the jacket-wall had fallen very considerably from its original temperature.

Now there could be but little doubt that in every engine-cylinder there must be a production of fog in the mass of the steam, the fog which might be termed *adiabatic fog*, and which was due to condensation in consequence of the work done by the steam. If this fog did not appear in the glass revealer, then it was clear that the glass revealer was not representing exactly the conditions of the steam-cylinder.

In Table 2 (pages 522–3), in comparing the two tests, the author stated that in No. 2 about twice as much heat passed in per unit of surface from the low-pressure cylinder to the cylinder-wall as in No. 1 test, and this although it had to pass through a greater thickness of water and drops on the surface. The author stated that this proved, that this water did not interfere with the passage of heat through the cast-iron walls; but if attention were paid to the thermal gradient of the cylinder-walls, it would be seen that the rate of transmission per degree difference of temperature on the two sides of the wall was about the same in both experiments.

The writer has been carrying out experiments on the condensation of steam produced by the action of cylinder-walls. The experiments have been very difficult to carry on, owing to the great effect produced by apparently very trifling differences in the condition of affairs in two trials intended to be identical. The object of his own trials had been to obtain quantitative figures, and as it had proved so extremely difficult to secure that, the figures would be repeated in a series of trials under what were intended to be exactly similar conditions, when every precaution had been taken to get rid of causes of error. He felt that the author's experiments must be regarded as giving qualitative rather than quantitative results. Very slight differences in the dryness condition of the steam, for example, exerted enormous effects on the condensation by the metal walls with

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which the steam came in contact, and, as was well known, it was extremely difficult to determine quantitatively the actual dryness of any given sample of steam.

In conclusion, however, the writer would like again to thank the author for his continued experiments on this very important question of cylinder condensation.

Mr. W. H. Northcott wrote that he was not quite sure how far the author's very interesting experiments really represented what took place in a steam-engine cylinder. As pointed out by M. Nadal (page 526), the conductivity and specific heat of glass were very different from those of cast-iron. These differences must have an important influence upon the thermal states of iron and glass surfaces exposed to steam of varying temperatures. Beyond this the writer would expect that the glazed smooth surfaces of glass would be much more conducive to spheroidal segregation than the dull and comparatively rough surfaces of cast-iron cylinder-covers. Tate, Fairbairn, and other experimenters have also observed a strong affinity between glass surfaces and adjacent aqueous moisture, and this affinity might conceivably exercise some influence on experiments such as the author described. The radiation from the cast-iron cylinder in the centre of the glass cylinder would tend to reduce the deposition of dew upon the glass surfaces and to hasten its dissipation. It was quite possible that one disturbing influence might partly neutralise another.

M. Nadal concluded that the globules were formed in the steam in consequence of previous cooling, and before the steam came in contact with the internal surfaces of the revealer at all. If that were the case, then these surfaces had as little to do with the condensation as a wet pavement had had in causing the rain that wetted it. The globules seen on the glass sides of the revealer had been precipitated there because the glass sides were in the way of the steam, just as rain-drops were precipitated against a window-pane.

The writer did not accept this as a satisfactory explanation of initial condensation, but the fact that, when the author purposely cooled the steam on its way to the revealer, the moisture deposited on the glass walls was increased, lent some reason to M. Nadal's view.

M. Nadal attempted only to explain Mr. Donkin's results, but the writer would like to know how he explained the presence of the rain-drops in the steam when the steam was not purposely cooled. The explanation was apparently obvious, but a quantitative analysis of the heat that would satisfy the explanation was not so easily obtained.

Many years ago when the author kindly showed the writer his then revealer in action, the latter came to the conclusion that the moisture was deposited as a film, that this film rapidly segregated into drops, globules, or spheroids, and then disappeared by re-evaporation. A writer in the "Engineer," who had seen the revealer working, described its action in words that very exactly described what he himself saw. The author however said (page 514) "that there cannot be any thin film of condensation water on the internal surfaces of steam-engine cylinders, whether the cylinder is relatively hot or cold, as there has so often been supposed to be."

Apart from M. Nadal's hypothesis he did not see how spheroids of water could be deposited as spheroids on either glass or metal surfaces. If by the action of the metal surface a drop of water was formed, then the latent heat of the steam from which the drop of water was derived must be absorbed by the metal. How could this heat be absorbed by the infinitely small area formed by the contact of a surface with a spheroid, and which spheroid, it might be noted, would be formed *after* parting with heat and not before? The author and M. Nadal were agreed that the heat-absorbing properties of cast-iron were much greater than the heat-emitting properties, in the proportion according to M. Nadal of about 360 to 1, but the writer did not see why this should be so, provided other conditions were the same. The disparity did very probably exist, but might it not arise, not from the properties of the metal surfaces, but from the very film contact in which the author disbelieves. If the water were condensed as a film and re-evaporated as a spheroid, the observed results would be explained. On the whole he would expect better results from the author's early form of revealer than from the form now described.

Mr. Donkin, in further reply to the discussion and communications, wrote that as to the particular shape the water assumed, condensed from the steam on the cast-iron walls, the words " drops " and " films " were rather indefinite. As seen in the revealer fixed on many steam-engines of various types, they were hemispherical, Plate 72 ; that is, half spheres very regularly shaped, adhering to the walls on their flat side, the convex or hemispherical side being towards the steam. They touched therefore, not on a point, but on a flat circle equal to their diameter, and thus offered a considerable surface for exchange of heat between the walls and themselves. The hemispherical side had a surface for re-evaporation much larger than the flat side. The large number of very small hemispheres of water might or might not act like an even continuous film having the same total surface. Many writers had supported the " continuous-film " theory. Dry patches existed between the hemispheres, and these doubtless were modified by the greater or less smoothness or polish of the turned surfaces of the cast-iron, especially if there were slight traces of grease or oil on them. On rough cast-iron surfaces the forms assumed by the water would probably be less regular in shape. The diameter of the hemispheres depended upon the difference of temperature between the steam and the wall. The greater this difference, the larger was their size. On smooth vertical surfaces the large drops ran down, joining with others, and tended to form flat irregular-shaped films of unequal thickness. In their descent they ran away from and avoided the greasy portions.

Referring to the heat-absorbing and heat-emitting properties of a cast-iron wall, the question of time should also be considered ; for the two operations it was probably not the same. This was shown in one of the experiments ; the heat entered the wall much quicker than it left it. The walls did not get hotter and hotter.

In reply to Mr. Rounthwaite (page 539), the diameters and strokes of the compound vertical engine were given on page 509 of the Paper. Sir Frederick Bramwell mentioned (page 539) the early interesting experiment of Mr. Cowper in 1859 with a boiler glass water-gauge attached to a steam-cylinder. The author many years ago had tried this, the simplest form of revealer ; at the time he did not know this experiment had been made before. The result was not considered satisfactory, as the diameter of the glass gauge was too small to show well the effects of condensation and re-evaporation, and hence the larger diameters that were now adopted.

As to the question of testing the percentage of water in the steam of the revealer and in the steam-cylinder, the author had made no experiments, nor did he know of any reliable instrument for this purpose. The steam calorimeters now in use often gave discordant results.

The Institution of Mechanical Engineers.

PROCEEDINGS.

November 1900.

The November Meeting was held at the Institution on Friday, 16th November 1900, at Eight o'clock p.m.; Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S., President, in the chair.

The Minutes of the previous Meeting were read, approved, and signed by the President.

The President announced that the following two Transferences had been made by the Council:—

Associate Members to Members.

Arnold, William, ...	Birmingham.
Sime, William, ...	London.

The following Paper was read and discussed:—

"Capacity of Railway Wagons as affecting Cost of Transport;" by Mr. J. D. Twinberrow, of Newcastle-on-Tyne.

The Meeting terminated at Five Minutes to Ten o'clock. The attendance was 111 Members and 60 Visitors.

CAPACITY OF RAILWAY WAGONS AS AFFECTING COST OF TRANSPORT.

By Mr. J. D. TWINBERROW, of Newcastle-on-Tyne.

Railway Working, 1889–1899.—The course of railway finance during the past decade is indicated by Figs. 1 to 8, pages 559–560, which exhibit graphically some of the particulars summarised in the Annual Report to the Board of Trade. Fig. 1 shows the total mileage, amount of capital, and amount paid in dividends by the railways of the United Kingdom. It will be noted that the mileage exhibits an increase of 8·8 per cent. upon the total for the last year of the preceding decade; capital has increased by 31·4 per cent., a portion of the advance being due to nominal additions resulting from the division of ordinary stock; 14·5 per cent. has been added to the amount available for dividend, but upwards of 3½ millions of this total are derived from sources other than the net receipts of railway working; the rate of increase of capital is thus more than twice as rapid as the growth of the amount available for meeting interest charges.

The amounts of gross receipts and working expenses are given in Fig. 2, the latter item being plotted to nearly double the scale of the former, so that the difference in the inclination of the curves represents the divergence of the ratio of working expenses from 50 per cent. The individual contributions of the passenger, general merchandise, and mineral traffic are shown in Fig. 3; the increases in the period referred to are 34 per cent. from passengers, 27·5 per cent. from merchandise, and 28 per cent. from minerals.

In Fig. 4 are given the number of passenger journeys yielding the above receipts, and the number of train-miles necessitated by the traffic. Excluding season-ticket holders the journeys have increased by 42·8 per cent.; but in the absence of information as to the number of passenger-miles the actual increase of the service rendered cannot be stated. The passenger train-mileage is 34·5 per cent. greater, so that the earnings per train-mile have diminished slightly during the period under review.

The tonnage of merchandise and minerals, together with the receipts and the train-miles worked by all goods trains, are given in Fig. 5. The tonnage handled is 36·9 per cent. greater in the case of merchandise and 40 per cent. in minerals; the train-miles are 27·8 per cent. more, practically the same proportion as the advance in receipts. As the rates per ton-mile do not appear to have experienced a considerable reduction, the paying load per train-mile has remained stationary, but the average length of haul has decreased. From Fig. 6 it is clear that the earning capacity of the trains is slightly less, whilst the cost of working them is increasing; any improvements which may have been effected in the construction of locomotives and rolling stock and in engineering practice have not been of sufficient moment to counteract the increasing cost of labour and materials. The detailed composition of the working expenses is given in Fig. 7; the serious rise in the cost of the traffic and locomotive departments will be noted, the former being particularly affected by change in the rate of wages, and the latter by the increased cost of fuel and materials. Reference to Fig. 8 may afford some basis for speculation as to the future course of railway dividends.

The principal factor in reducing the cost of a product is the economy of labour in its manipulation, and this is effected in modern industries by improvements in plant or tools, whereby both the output and the remuneration of labour are increased. The results of railway working in the British Isles afford no evidence of the adoption of that principle to this important branch of industry. The useful products of railway working are the passenger-mile and the ton-mile; since these units determine the earnings, they should also form the basis for calculating the costs; but it is customary to refer the expenses of British railways to the arbitrary and unmechanical unit of the train-mile. This naturally tends to direct effort towards the reduction of costs per train-mile, rather than towards developments

Railway Working, 1889–1899.

Fig. 1.

Capital, Dividend, and Miles Open.

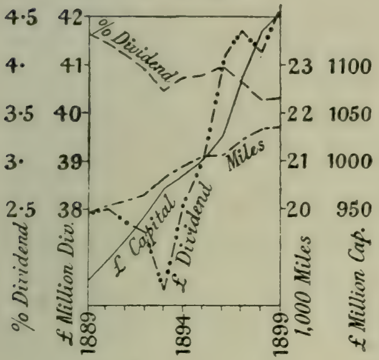


Fig. 2.

Amount of Receipts, and Expenses.

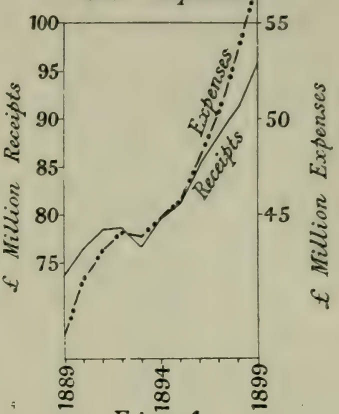


Fig. 3.

Receipts from Passengers, Merchandize, and Minerals.

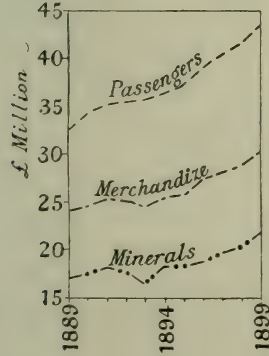
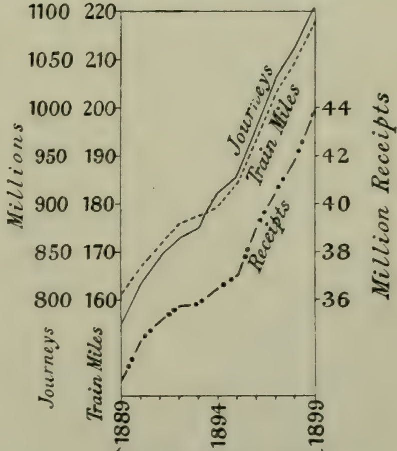


Fig. 4.

Passenger Journeys, Train Miles, and Receipts.

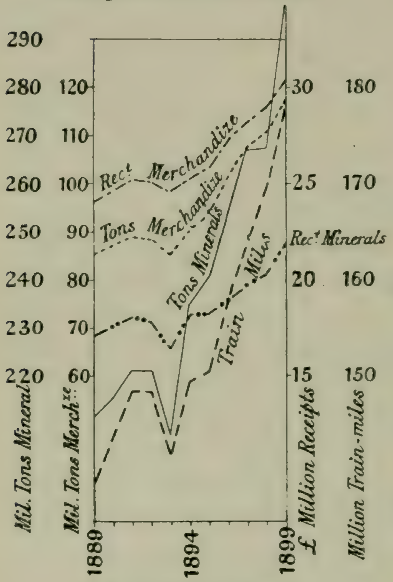


(Cp. Plate 20, 1898.)

Railway Working, 1889–1899.

Fig. 5.

Goods Tonnage, Receipts, and Train-miles.



(Cp. Plate 19, 1898.)

Fig. 6.

Receipts and Expenses per Train-mile.

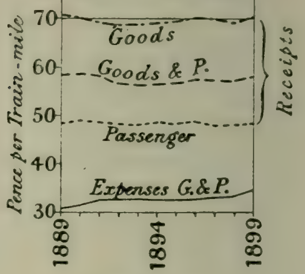


Fig. 7.

Working Expenses per Train-mile. England and Wales only.

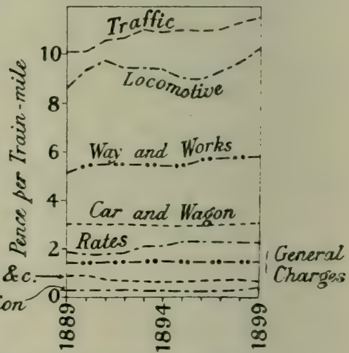
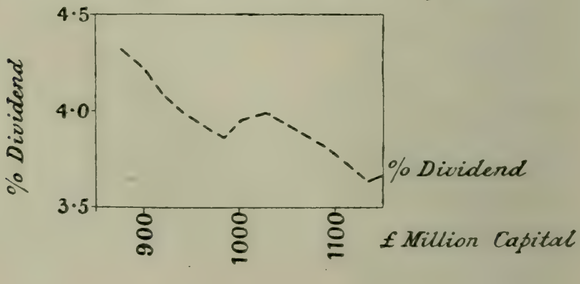


Fig. 8. *Variation of Dividend with Increase of Capital.*



of which the immediate effect may be an increased cost per train-mile, though the final ratio of earnings to costs may be improved.

This ratio may be improved in either of two ways: firstly, by refining to the utmost possible extent the stock and plant employed to work trains of constant earning capacity; or secondly, by the efficient utilization of machinery and vehicles of greater earning capacity, permitting the realization of larger receipts per train-mile. The economies possible under the first heading are very limited, because refinement of design can be expected to reduce the cost of fuel and repairs by only a small amount, and will hardly affect the labour employed in working trains. If it were practicable to design a locomotive of such excellence as to save all the fuel, and at the same time avoid any increase in the cost of repairs, the result in working standard mineral trains would be a saving of only 3*d.* per mile, or say 25 per cent. of the cost of locomotive power per train- and per ton-mile. If, on the other hand, the average gross train-load were doubled, by the efficient employment of engines of 100 per cent. greater hauling power, the cost of fuel per train-mile would be increased to 5$\frac{3}{8}$*d.*, and 50 per cent. might be added to the cost of repairs per mile run; yet the final result, without in any way trespassing on the limits of practicability, would be a saving of upwards of 30 per cent. in the cost per ton-mile. But apart from any change in the motive power, the gross earnings per train-mile may be increased by employing vehicles of greater earning capacity, the saving in tare weight being replaced by an equivalent amount of paying freight. The author will therefore endeavour to show the extent of the possible saving, briefly indicating the difficulties which stand in the way of its realization.

Goods Traffic.—The movement of goods upon the railways of the United Kingdom exceeds 415 million tons yearly; general merchandise accounts for 28 per cent. of this total, the remaining 72 per cent. being composed of minerals. The mileage worked by goods trains is upwards of 177 millions, and in 1899 the gross earnings amounted to £52,116,994, of which about 42 per cent., or £21,834,477, was yielded by mineral traffic. Thus minerals constitute nearly three-fourths of the bulk, but yield little more than three-eighths of the revenue. The reason is that the schedule rates for minerals are lower than those charged for general merchandise, whilst the average haul is probably shorter. Yet the fact that the mineral wagons are loaded to their full capacity and can usually be dealt with in full train-loads, whilst there is no expense involved in collection and delivery at terminals, renders this traffic fully as remunerative as that which is carried at higher schedule rates.

It is obvious that any saving which may be effected in the tare weight of vehicles employed in this class of traffic will permit of an equivalent addition to the paying load without increasing the cost of working; that is, a greater weight of freight will be moved by working the same train-mileage, or the same traffic may be handled with a proportionate reduction in the train-mileage. The average tare weight of a British mineral train is about 39 per cent. of the gross load, so that 61 tons out of every 100 tons of full trains are paying freight. If one-third of this dead weight is saved by the introduction of wagons of increased capacity, the tare is reduced to 26 per cent. of the gross, while the net load is increased to 74 tons out of every 100 tons. This is equivalent to an advance of upwards of 21 per cent. in the gross receipts; or if the receipts remain constant, the train-mileage necessary may be reduced by 17·5 per cent. A train of standard 10-ton wagons will hold a paying load of 0·52 ton per running foot, about one-sixth of the total length being accounted for by the vacant spaces between adjacent headstocks. By increasing the capacity of the wagons, a paying load of 0·84 ton per foot can be readily obtained, and thus the capacity per unit of length of train or siding is increased by 62 per cent.

The assumption is sometimes made that the short haul characteristic of much of the goods traffic in this country will prevent the realization of the economy which has followed the introduction of rolling stock of high capacity on American railways; but this conclusion is hardly warranted by a consideration of the influence of the decreased mileage per ton upon the working expenses. The effect of the shorter haul is to enhance the relative importance of terminal charges, and to increase the ordinary working expenses per train-mile; because the daily mileage obtained from engines and wagons is thereby decreased. It therefore tends to emphasize the necessity for increasing the gross receipts per train-mile; whilst the multiplicity of junctions and sidings gives additional importance to the compact formation of trains of high-capacity rolling-stock.

In dealing with general merchandise, the British trader expects to have each individual consignment loaded into a separate vehicle and forwarded direct, without delaying the wagon to fill up with other goods for the same destination. Many British railways have analysed the traffic leaving important goods yards, and find that the average load per wagon is less than two tons: from which they conclude that small wagons will yield a better actual ratio of load to tare than larger vehicles of greater nominal capacity, whilst the proximity of important towns on most of the great railways tends to diminish the advantage and to increase the delay incidental to the practice of transhipping from partially loaded wagons at intermediate junctions. The total cost of working goods trains approximates to one penny per truck per mile; but the practice of cutting off a wagon or two at a certain junction will not save this amount, as there is very little difference in cost of working between a partially loaded train and one which is loaded right up to the capacity of the engine. But transhipment might be practised with advantage in connection with long-distance traffic, when it promises to release daily a sufficient number of vehicles for enabling a reduction to be made in the train-miles necessitated by that traffic.

On the whole the carriage of general merchandise does not offer so favourable a field for the introduction of high-capacity stock as does the mineral traffic of this country; but certain classes of merchandise might with advantage be loaded in large wagons of low tare, such as timber, bricks, rails, rolled steel-work, etc., which in any case involve the provision of special rolling stock, and which are generally dealt with in large consignments. The Great Western Railway have built some bogie-wagons for rail traffic, each capable of loading 40 tons, the tare being 17 tons 7 cwts. These wagons have a trussed steel underframe 45 feet long, provided with fixed bolsters for the reception of the load; the solebars are supported by suspension bolts bearing in spherical washers, secured at their lower ends to cross bars passing beneath the bogies, while the upper ends of the bolts are attached to the side frames of the bogies. This style of bogie dispenses with the heavy transoms and bolsters needed to transfer the load to the customary bogie pivot, and thence to the side frames of the bogie truck.

Long Wagons.—It is possible to construct a wagon having a body of twice the standard capacity with an increase of only one-third in the tare weight. The resulting gross load per axle will then be 14 tons; but since the enlarged capacity must be obtained chiefly by increasing the length, the wheelbase of the four-wheeled vehicle will be so great as to occasion some inconvenience on the sharp curves of sidings in colliery yards and factories, and will involve greater resistance to traction on ordinary curves; it will also necessitate the removal of short turntables and traversers. Both the Great Western Railway and the London and North Western Railway are experimenting with steel coal-wagons of 20 tons capacity; the wheelbase is 12 feet, and the bodies are provided with side doors for unloading; the tare of the Great Western wagon is 8 tons 6 cwts., whilst that of the London and North Western has been reduced to 7 tons 18 cwts. by the expedient of employing thinner plates and a lighter underframe.

To overcome the objections due to length of wheelbase, the author proposes mounting the axles in a cantilever extension truck, which supports the underframe by means of a pair of laminated springs carried upon each end of the frame extending beyond the axles, and by intermediate helical springs. This idea has been worked ont in the designs shown in Figs. 9 and 10, Plate 76, and Plate 77.

In preparing the design which is shown by Fig. 12, Plate 77, it was decided to limit the load per axle to $12\frac{1}{2}$ tons. This represents an advance of about 50 per cent. on the existing standard practice; and though a higher load would probably be justifiable for main-line work, it was not considered desirable in this case on account of the limited strength of colliery lines and sidings. The axles, which have a diameter of 5½ inches in the centre and journals 10 inches long by 5 inches diameter at each end, are mounted in pressed-steel bogie-frames at a distance of 7 feet 6 inches apart, centre to centre. The axle-boxes support the frames through short coil springs of moderate flexibility. The frames are stayed by two channel transoms 10 inches by 3 inches by 22 lbs. per foot, braced by flat bars 2½ inches by ⅜-inch.

The body is supported by two laminated springs at each side, placed 12 feet apart centre to centre; and as the span of the plates is 4 feet, the effective length of the base upon which the body rests is 16 feet. The friction of the plates of these springs is depended upon for damping out any tendency to synchronous oscillation in a fore and aft direction. The deflection of the laminated springs under load brings into action two coil springs at 4 feet 6 inches centres on each side; the body is thus supported on eight springs, so distributed as to avoid heavy bending moments on the sills. The sides of $\frac{3}{16}$-inch plates are riveted directly to the sills, and are stiffened with T bars 3 inches by 3 inches by 7 lbs., and finished with a curb of L bar 2 inches by 1½ inches by 3·3 lbs. per foot.

The body is divided into two hoppers by means of inclined plates converging to openings at 13 feet 4 inches centres, and therefore delivering the load near each end beyond the axles. The hopper doors are formed of steel plates stiffened by L bars 3 inches by 3 inches by 7 lbs. per foot, riveted to their lower sides; they are supported by means of rollers 3½ inches diameter, running upon the lower flanges of Z bars 6 inches by 3 inches by 14 lbs. per foot. The doors are worked by flexible steel-wire ropes connected to a drum at each end of a cross-shaft, as shown, so that they are opened or closed simultaneously, when the drum-shaft is rotated by means of the handwheels and gearing. The gear may be arranged to work the doors independently, if required.

The brake-blocks are operated by means of hand-levers at both sides of the wagon. These are retained in position by means of catches engaging with suitable notch bars when worked by a horizontal movement of the handle, which is connected to the body of the lever by means of a vertical pivot-pin. The catches are connected by means of a cross-shaft and pull-rods, so arranged that the brakesman may disengage the catch on either or both sides by working the handle next to him, but can cause the engagement only of the catch attached to the lever which he is working.

When these wagons are required to work with coal-tips arranged for end-on discharge, the bottoms are plated flush, and the ends are pivoted at the upper corners, so that they will swing open when the latches are released, the platform of the hoist being suitably inclined in the customary manner. Side doors may of course be fitted, either alone, or in addition to those in the other positions.

A simple form of wagon for carrying rails, timber, steel plates, and sections, &c., is shown in Fig. 13, Plate 77. The arrangement of the bearing springs is similar to that in the preceding example; but since the length of the body has been extended to admit of rails, &c., 30 feet long, the length of wheelbase is increased to 12 feet. Each bogie-frame is built up of two channels 3½ inches by 1½ inches by 8 lbs. per foot, uniting the cast-steel axle-guards, and trussed by means of diagonals 4½ inches by 2 inches by 10 lbs. per foot attached near the lower ends of the guards, which are further united by double bar-stays 2 inches by ½ inch. The frames are connected transversely by L bars 3 inches by 2 inches by 5·7 lbs. per foot, with lattice bracing in the vertical plane, and diagonal ties of L bars 2½ inches by 2½ inches.

The sole-bars of the body consist of channels 9 inches by 3 inches by 22 lbs. per foot, united by the headstocks and by four cast-steel transoms; the latter have flanges at each side to receive the floor plating, and are extended upwards to form bolsters, and outwards above the sole-bars to meet bulb L bars 7 inches by 3 inches by 14 lbs. per foot, which form the sills and sides of the shallow body. The great depth of the transoms and their firm union to the sills and sole-bars are expected to ensure great transverse rigidity, whilst the steel floor-plates provide efficiently for the horizontal bracing.

The adoption of the bogie system will eliminate the objection due to sharp curvature, but will still necessitate the removal of turntables, and the alteration of terminal plant which includes hoists, tips, and lifts having short platforms. This class of wagon may have a gross weight double that of the four-wheeled type, or say 56 tons when the permissible axle-load is 14 tons; but the tare need not be as great as that of two four-wheeled wagons, because one half of the relative numbers of headstocks, of buffing and draw gears, and of end plating is saved. The customary design of shallow underframe necessitates trussing to support the span between the centres of the bogies; or the soles may be pressed from steel plates into a form which will afford greater depth towards the middle of the span. But in order to secure maximum rigidity with minimum additional material, the author proposes to make each side of the body as a vertical plate-girder, and has adopted this idea in the design of a double-hopper wagon, as shown in Fig. 11, Plate 76, and Fig. 14, Plate 78. It is intended that the gross weight of these wagons shall not exceed 50 tons; but, by slightly increasing the dimensions of the bodies and by strengthening the springs, the wagons may safely carry 42 tons without exceeding a gross weight of 56 tons, that is, 14 tons per axle.

The double-hopper coal-wagon of 36 tons capacity, Fig. 14, Plate 78, is 42 feet long over headstocks, and 9 feet and $\frac{1}{2}$ inch high from rail to top of curb when unloaded; the vertical sides of $\frac{3}{16}$-inch plate provide a pair of longitudinal girders 6 feet deep, the lower flange of L bar 6 inches by 3 inches by 11 lbs. per foot is horizontal, whilst the upper flange of L bar $4\frac{1}{2}$ inches by 3 inches by 9·2 lbs. per foot is set down to meet the headstock at each end; the webs are stiffened by T bars $3\frac{1}{2}$ inches by 3 inches by 7·7 lbs. per foot, the upper ends of alternate bars are united transversely by bulb flats 5 inches deep with flanged gusset-plates. The inclined end-plates of the hoppers form an additional transverse brace, whilst deep vertical plates framed in with angles provide a rigid transom over each bogie centre. There are also two vertical flanged plates supporting the hoppers near the middle of the wagon's length; and a tubular longitudinal member built of two pressed plates unites these vertical plates to the bogie transoms, and affords a passage for the continuous draw-bar and the brake pull-rods. The use of sliding doors permits the hoppers to be continued downwards to 15 inches or less above the rail-level. The roller paths for the doors are formed of outwardly turned channel-bars, which carry the wire-rope winch near their centres.

When the self-discharging of the load is not an essential feature, the construction is modified as shown in Fig. 15, Plate 78. The body of this wagon is 36 feet long, and the side girders are set down to be flush with the floor line for a distance of 7 feet 3 inches from each end; openings 4 feet wide are provided in each side above the bogies, and the doors are arranged to run upon anti-friction rollers travelling on the top flange of the girder. The floor plating is riveted to framed transoms 15 inches deep over the bogies, and to seven intermediate transoms of rolled joists 7 inches by $3\frac{3}{4}$ inches by 18 lbs. per foot.

In order that long wagons may work safely in contact with shorter vehicles over sharp curves, it is necessary to equalize the buffers. This is effected by uniting the buffer stems rigidly by means of a rectangular frame, and by pivoting the frame on the centre line at the point where it is intersected by the centre line of an adjacent standard wagon when on a curve; the buffer frame is not rigidly united to this pivot, but bears against a laminated buffing-spring resting in a cradle which is tied to the pivot. The buckles of the buffing-springs are united by a continuous draw-bar, when it is considered advantageous to have a continuous draw-bar; and as the draw-bar spring must be sufficiently strong to cushion the whole tractive force, it is almost useless for reducing the concussion on individual wagons; a lighter helical spring is therefore interposed between the buffing-spring beam and the pivot, and this must be compressed by a pre-determined amount before the draw-bar spring comes into action.

The wheelbase of the bogies, shown in Fig. 16, Plate 79, is only 5 feet in length, and the tendency to bind diagonally with the rails would hence be considerable, if flange pressure alone were depended upon to keep them central. The customary central pivot on the bogie is in consequence dispensed with, and the load is transmitted to the bogie transoms, which consist of channel-bars 10 inches by 3 inches by 22·5 lbs. per foot, through two pairs of laminated springs placed transversely on shoes having a large area of bearing surface. This disposition reduces the bending moments on the main and bogie transoms by more than 50 per cent., as compared with the general practice. The bogie frames are supported by helical springs above each axle-box; the coils are double, and the outer ones alone act when the wagon is unloaded. The connection to the main frame is effected by means of links radiating from each corner of the truck, and provided with cushion springs, which are compressed by angular and lateral displacements, and which ensure a prompt return of the truck to the normal position. The resistance to traction is in stable equilibrium with the tractive force, which is applied through the leading pair of radiating links. The bogie frames in this example are of cast steel.

Terminals.—The successful introduction of high-capacity wagons, either of the four-wheeled type, as tried on the Great Western and London and North Western Railways, or of the eight-wheeled bogie pattern, is entirely dependent upon a satisfactory solution of the question of terminals. The substantial economies promised will doubtless justify a very considerable expenditure of capital in the alteration of existing plant; but the carrying out of such a change without interfering with the normal course of trade will demand careful consideration, and, as many of the terminals where the loading and unloading are carried on are private property, it is not probable that the owners will incur the cost of alteration to suit an innovation, from which the railways will be the immediate gainers.

In connection with the coal traffic, the terminals will be found to fall under the following classification :—

(*a*) Producer's terminal. Colliery yard.
(*b*) Consumer's terminal. Industrial establishments, &c.
(*c*) Trader's depôt. Distribution by cartage.
(*d*) Shipping terminal of Railway or Dock.

Terminals of Class (*a*) will usually admit long wagons without alteration, but the levels of the screens and filling spouts limit the height above rail-level. The weighbridges can usually be adapted for bogie-wagons, if the load on each bogie is taken separately.

In the older establishments of Class (*b*) short turntables and sharp curves with light rails are of frequent occurrence, the arrangements for shunting are often of a primitive nature, and would be unequal to the task of moving wagons of greatly increased gross weight. In the North Eastern districts of England the coal wagons are invariably of the self-discharging hopper type, and industrial establishments are usually fitted to take advantage of this inexpensive method of unloading. An instance of the influence of terminal arrangements on cost of handling may be quoted: a firm, having a large daily consignment of coal, contracted for the labour of unloading the mineral at the various points of consumption at the rate of $\frac{7}{8}d.$ per ton, and found that the unloading of wagons provided with side doors, which were sent with a special consignment from another district, necessitated an increase of the cost to as much as 1*s.* 2*d.* per ton. Self-discharging hopper-wagons are also used to great advantage in some of the large gasworks in Midland towns. Many large works situated in densely populated districts have not sufficient yard area to allow of the elimination of turntables; the working of their traffic in large wagons can then be effected only by the construction of a depôt, into which the railway wagons would discharge with the least possible delay, and from which the coal would be distributed to various points within the works by means of conveyors, or by small wagons running upon the existing lines. The proprietors cannot be expected to make the necessary alterations in order that the carriers may reduce the cost of transportation. The suggestion may be made that the provision of such depôts on consumers' premises at the cost of the railway company is worthy of consideration, when the volume of traffic is such that the annual saving in transport will liquidate the capital charges on the cost of the new plant. The interest of private owners in the introduction of high-capacity wagons is at present limited to the advantage of lessened first-cost and repairs per ton carried. It might be possible to afford them an opportunity to share in the reduced cost of transport, by altering the basis of the charges from the net to the gross tonnage, reducing the rate in the inverse proportion of those weights. Thus if the existing net load be 61 per cent. of the gross weight, the rates when charged on the latter would be reduced by 39 per cent., in order that the revenue yielded by the traffic might be unaltered; but the change would afford the trader a direct incentive to reduce the proportion of tare by adopting high-capacity wagons.

Traders' depôts of Class (*c*) consist frequently of a length of siding with space for bringing carts alongside the wagons, from which the load is discharged through side doors. When the tonnage dealt with daily is insignificant, the carts are loaded directly from the railway wagon as required, and the wagon itself serves as the trader's store; a small wagon is therefore preferred, as it lessens the liability to a charge for demurrage. Three wagons of 10 tons capacity must be kept in constant service, in order to supply the requirements of a retail trader using say 5 tons daily; but if a depôt were constructed with a capacity of say 40 tons, the trader's requirements would be met by the use of a single large wagon arriving at eight-day intervals; and if the depôt be situated one day's journey distant from the colliery, and one day be allowed for emptying and refilling, the use of the wagon will be required for three days in each period of eight days; therefore the average daily employment of tonnage will be $\frac{40 \times 3}{8} = 15$ tons, or 50 per cent. less than the capacity employed daily in maintaining an equal volume of retail trade on the old system. Many of the coal terminals in London consist of parallel lines of way spanning the upper portion of hopper-shaped stores, from which the road vehicles are filled at a lower level. The lines are usually connected by short traversers, or by turntables, and would require to be remodelled for accommodating wagons of high capacity; but, owing to the great volume of the traffic and the considerable distance over which it is transported, a small economy per net ton-mile will justify the expenditure of a considerable sum in order to effect the necessary alterations.

The terminals of Class (*d*) present a variety of features, differing in accordance with the practice of the various districts from which coal is shipped.

Various Methods of Shipping Coal.—Some examples of typical plant are illustrated by Plates 80 to 84. Fig. 17, Plate 80, illustrates the Scotch practice. The plant consists of a pivoted hydraulic jib-crane, fitted with blocks and ropes or chains for lifting and for tilting, and of a simple cradle of sufficient length to accommodate the wheelbase of an ordinary wagon. The cradle rests upon a seating, with its rails in line with those of a length of siding, from which the loaded wagon is pushed into place, being retained by the curved ends of the rails of the cradle against which the leading tyres rest; the cradle is then lifted and swung over the hatchway, and the tilting gear is raised in order to discharge the load through the end doors. The cranes being of an ordinary kind can be adapted to the loading and discharge of all classes of heavy and bulky cargo; the only special feature is the cradle, which however is of simple and inexpensive construction. The practice of swinging the wagon out beyond the quay enables the coal to be discharged from a lower elevation than that necessary, where the passage of the mineral from the quay line to the hatchway is effected by gravitation down inclined spouts.

End-tipping wagons exclusively are also used in the Welsh coal trade; but the method of tipping is not the same. The wagons are usually run upon roads parallel to the quay, turned at right angles thereto, and run on to the platform of a hoist, which is then raised to the requisite elevation, and tilted to discharge the load into an adjustable spout projecting over the hatchway of the vessel alongside; the empty wagon is then lowered, turned, and run on to the empty roads. An illustration of a Welsh coaling-tip is given in Fig. 18. The steel tower supports rigid guides for the hoist platform; the chains for working the platform are carried over pulleys on the top beams to hydraulic jiggers bolted to the side of the tower. The rails carrying the wagon are mounted upon a subsidiary frame hinged to the main platform. Much care has been devoted to the design of these tips, and many different kinds have been employed to meet special conditions, or to economise the working power. At Barry Dock, for instance, some of the tips are provided with high-level approaches; the necessary elevation is attained at the expense of the shunting engine; and when lowering the wagon the hoist returns water under pressure to the mains. Some of the tips are adjustable in position along the quay, to suit the pitch of the hatchways in different vessels. It is perhaps desirable to mention that the development of this kind of plant is due to the use of a class of wagon, which does not present features of conspicuous advantage for the purpose it is employed for.

Durham and Northumbrian coals are transported in self-discharging hopper-wagons, the shipment being effected from timber staiths, which contain hoppers fitted with spouts projecting laterally over the vessels lying alongside. Tyne Dock, near South Shields in County Durham, holds the record for the monthly and yearly tonnage placed on board. The author is indebted to the chief engineer of the North Eastern Railway for the use of the drawings of the staiths, from which Plates 81 to 83 have been prepared. It will be noted that the arrangement is entirely self-acting. The wagons are run by gravitation down the central roads, and in passing down the short length of sharp inclination acquire sufficient impetus to travel through trailing points on a rising grade, by which they are brought to rest and their motion is reversed; in returning they then take the facing points leading to the hoppers, where they discharge their loads and run back on the "empties" road. The ease and rapidity of the process, the small number of men employed, and the absence of costly machinery, are features which stamp this plant with the character of an engineering achievement of the highest order. If such staiths were introduced in districts where the end-discharging wagons are in vogue, the erection of a simple gantry over each hopper would enable these vehicles to tip their loads, so that they could be continued in service until gradually replaced by high-capacity hopper-wagons. Bogie-wagons of any length would be readily accommodated; and owing to the diminished friction of large wagons fitted with axle-boxes for oil lubrication, the gradient of the roads might be reduced.

Fig. 23, Plate 84, shows an American method of dispensing with the long approaches necessitated on low-lying shores, if locomotive working is retained. Here the incline is laid with a maximum gradient of 1 in 3, and has a narrow-gauge track between the rails which terminates in a pit at the foot of the incline; a four-wheeled pusher or haulage mule runs on this track and rests in the pit, whilst the loaded cars are shunted to the foot of the grade; it is then drawn up from the pit, and engages with the rear coupler in order to push the cars up the incline. Long cars which are not provided with self-discharging hoppers are tipped by rolling them over laterally. Among the special designs for this purpose one of the most successful is the McMyler dumper, which is shown in Fig. 24. It consists essentially of a steel tower, forming a guide for a platform, which latter is provided with a rigid side toward the vessel to be loaded. Wire ropes are attached to the top of this outer side, and pass upwards over guide-pulleys to a counter-weight running on the posts at the rear of the tower; the hoisting ropes are attached to the lower part of the same outer side of the platform, beneath which they are led under guide-pulleys, rising thence to the top of the tower, and passing back to the hoisting winch. The platform is raised by the combined action of the ropes until the outer side meets an adjustable stop, which checks the descent of the weights; the pull of the hoisting ropes proceeds to tilt the platform, and brings the car into contact with the counterweight ropes; these bind it firmly against the rails, whilst the load is emptied into an inclined spout which terminates in telescopic trimming-tubes. With efficient arrangement of sidings to accommodate full and empty wagons, any ordinary shipping plant will be capable of tipping at a greater average speed than that at which the trimming of the cargo proceeds. The examples described are probably sufficient to prove that the process of shipping coal from large wagons has passed the experimental stage.

The author desires to express his thanks to Mr. J. F. McIntosh, for particulars of the Scotch shipping-crane, and for suggestion and encouragement in the preparation of this Paper; also to Messrs. P. W. and C. S. Meik for photographs and particulars of a hydraulic coal-tip; and to Mr. C. A. Harrison for drawings &c. of the staiths at Tyne Dock.

The Paper is illustrated by Plates 76–84 and 8 Figs. in the letterpress.

Discussion.

The PRESIDENT, in asking Mr. Twinberrow whether he had any remarks to make supplementing his Paper, said he was sure he expressed the feeling of all Members of the Institution, when he thanked the author for the considerable amount of labour and great ability he had shown in the preparation of the Paper.

Mr. TWINBERROW said he would like to add a word of explanation of the reason why he had included so many particulars of designs, which had not yet received the hall-mark of approval in practical trial. He felt, in putting forward his argument, that it was desirable to point out in some detail the means by which the advantages claimed could be realised. He was unable to draw upon existing practice, because at the time the matter was receiving attention wagons of that description were not in sight. It was now a matter of common knowledge that in America designs on somewhat similar lines had been worked out, and the company controlling the business had experienced a development which might be termed phenomenal, even for that land of rapid growth. Also a well-known English firm had recently devoted attention to the subject, and had now constructed some experimental wagons. He hoped that the discussion might elicit some information concerning those two developments, but, as he had explained, those particular designs were not available for the purposes he desired, and therefore the only course open was to produce designs which did not meet a demand, but by means of which it was hoped that a demand would be created. He felt flattered by the permission accorded to him to utilise the wall diagrams prepared for the presidential address of Mr. Samuel W. Johnson.*

Mr. JOHN W. WAINWRIGHT said it was with the greatest pleasure he heard of the abandonment of the timber construction in wagons,

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* Proceedings 1898, page 149.

(Mr. John W. Wainwright.)

and the use of modern metals in a better form. As to timber, heavy stocks had to be held; there was a great loss in conversion, and much subsequent deterioration in material, while the carrying capacity versus the dead weight was anything but what it should be. The author had made use of the best features of design, in some cases taken from well-known types of electric motor-cars—the cantilever extension type. The strains were somewhat different in motor-cars to those that obtained in railway working, and motor-cars were not subject to the heavy buffing that took place by the rough shunting on English railways. The author had very much increased the loads on the axles, which he himself considered was rather a serious item, but it really could not be helped. It had many bad effects, especially in works which were not constructed with regard to the main line, and there was a difficulty also in maintenance. There was also trouble with hot boxes. The design of bogie-wagon, as shown by the author, had some very good points in it, but in endeavouring to obtain lighter bolsters he apparently took the load from the centre, so as to decrease the bending moment, and had put in some large radial blocks; and he quite saw the reason why he had adopted that method. For this gave him practically beams with distributed loads, and constraining devices to suit a short wheel-base. He could not think that that would prove quite so easy for traction in practice under ordinary wagon maintenance as the centre pivot type; generally the weight of the car was carried on the centre pivot, and the rubbing or friction plates were separated. The author got rid of the side door in many cases, which was a great gain of girder strength, and one wished that the side door could be got rid of altogether. For facilities in unloading, the wagon was admirable, given the complementary conditions. The equalising buffer appeared to be an excellent thing, but it could not be claimed as novel, because it had been used on a southern railway for some years. From an engineering and practical railway point of view there was much to thank the author for. It was a distinct advance, but he was afraid that in the older works in England the cost of altering the fixed structures, necessitated by the use of the long bodies of the bogie and the other wagons shown, would be great. The compromise of storage requiring second handling would be very costly also, otherwise there was everything in favour of so distinct an advance in railway engineering.

Mr. W. R. S. Jones thought the subject was a great deal more interesting than was generally realised. He had himself thoroughly enquired into the subject for the Government of India, where notoriously low rates and low fares prevailed, and there had recently been introduced a practice that would compare very favourably with what was now proposed. He congratulated the author for having touched the most vital spot for good or evil in the whole range of railway economy. He spoke in that positive manner from the exhaustive enquiries he had made, which had brought out astounding results. The author had said (page 561), with much truth, that there was very little to be done in the improvement of locomotives. He might also have added—in the improvement of roads, for the English possessed the very best roads and the best examples of locomotives in the world. American locomotives had been introduced into various places, but he thought their trial would result, in many instances, in their abandonment. Therefore he thought possible improvements were limited to the vehicular rolling stock. In discussions such as the present, various units dealing with railway working were frequently quoted, and there were six or seven financial and other diagrams shown in connection with the present Paper, Figs. 1–8, pages 559–560. However, out of the whole of them, not one presented an atom of information necessary to the investigation of a case of that kind. Train-mileage he had heard defended in our meetings as being a mechanical term of some importance. It represented distance, but whether it represented constant weight was very doubtful. It varied, as was well known, on different lines. From figures obtained from the very clear statistics presented by the Government of India, the average weight of trains varied on different railways of the same gauge 56 per cent. Then in this Paper some volume and other percentages were drawn from the quantity of goods lifted. He ventured to say that they were of no value whatever, because, in a similar way to the train-mileage, they

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were weight without distance; and they did not in any way give what might be called the statistical volume of traffic, which was nothing but ton-miles, either gross ton-miles, or goods ton-miles. If, instead of that kind of information, any one had the industry and the luck to obtain information with regard to (1) the number of wagons in the country, which was said to be doubtful with regard to traders' wagons—he was told they varied from 400,000 to 500,000—and (2) the total tonnage carrying capacity of the stock used on railways, together with the total tonnage tare of them, it would then be possible to compare any new system such as the author had put forward, and to find out how that capacity could be replaced, and at what weight, whence the resulting saving in dead weight could be computed. It might be said that that would not be of much use, but he thought it would. The railway returns—he would not call them statistics, as they did not claim to be that—gave a certain amount of information from which little useful in this connection could be culled, but sometimes a scrap of information did fall from the lips of railway men in discussions such as the present. He recollected in 1876, at the Institution of Civil Engineers,* a discussion took place in which Mr. William A. Adams treated of the special subject of tare, and stated amongst other things that the duty of goods wagons and mineral wagons in this country amounted on an average to 200 miles per week. It appeared to be small; but perhaps even this mileage average was excessive. Secondly, Mr. Adams said that if the Midland Railway, with a certain number of wagons named, would adopt his practice of carrying 6 tons of load in a wagon weighing 3·75 tons instead of 4·75 tons, it would result in about 717 million ton-miles of dead haulage being saved per annum on that railway. At the same meeting, another scrap of information came out. It was given by the late Mr. Finlay, the General Manager of the London and North Western Railway, and related to the cost of carrying minerals. The weights and the cost per train-mile were given for point-to-point traffic between Wigan and London, and that was something definite. He himself deduced from the figures given in that way, that the average cost per 1,000 gross tons amounted to 99*d.* If that was fairly true, for English railways it was very good; any way, the London and North Western Railway were working very well indeed in regard to their locomotive power. Assuming that British wagons travelled on an average 10,400 miles per annum, which was the sum computed at 200 miles per week, then at one-tenth of a penny per gross ton-mile for haulage alone there would be a saving on 1 ton of wagon tare amounting to 85*s.* per annum. Roughly applying this data for the purpose of a rough example of what the financial results would be in what was advocated, and taking a British wagon, which was said to tare about 6 tons, reduced by the 26 per cent. as mentioned in the Paper, or even say by 1 ton per wagon for wagons of all kinds, and allowing them not to travel the distance per annum which it was said they did travel, which he disbelieved, but say 8,000 miles per vehicle per annum only, and according to the railway returns it was said there were 608 odd thousand railway wagons, and the traders' wagons were variously stated to be from 400,000 to 500,000, but he would take them at 450,000, making a total of 1,058,000 wagons—then if that was multiplied by the 8,000 miles travelled, at the rate of one-tenth of a penny per gross ton-mile for haulage, it would result in a saving in dead haulage per annum valued at £3,500,000. That was something to go upon in trying to induce people to adopt any new system, namely to give a money value to the suggested improvement. He was aware by previous and exact data, that that was not even one-half the case that could be made out in favour of better and lighter railway-stock. It would affect many other items besides the stock itself, not the least being the extension of storage room in large cities such as London, Manchester, Liverpool, and all those places where land was both scarce and dear. It seemed to him to be a problem that was of very serious consequence indeed, that was staring the railway companies of this country in the face. In India, where the capital was only 143 millions, and land and everything else was cheap, it was shown that the value of what was likely to be thrown out of use by the adoption of good rolling-stock amounted to over 10 millions of money; or to be more correct, future capital expenditure would be

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* Proceedings, 1875–76, vol. xlvi, page 105.

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avoided to that amount, and that was independent of advantages in other ways. He had already found that, in reference to improvements of that kind, general managers and government officials high up in the service did not always realise the value of a mechanical unit or percentage that might be put forward; but it was generally a clinching argument with all of them, and he ventured to say it would be the same in this country, to be able to reduce the proposed advantage to a currency value in pounds, shillings, and pence. They were much more likely to listen to it then than to percentages or train-miles and such terms, always of indefinite value.

Before making any alterations or additions to the rolling stock of a railway, it was generally prudent to see what was being done with the stock which already existed, whether the work was being carried on properly; because if old stock were being worked badly, no amount of improvement in the new would do any good. The most perfect machine in the world in bad hands would not do its quantity of work, whereas if it were worked properly up to its utmost capacity, then improvements might take place in the machine itself. He would take an instance, and try to compare it with the best data available. He could not compare it with English statistics, because none existed, and therefore he would try by analogy to bring something forward with regard to the working of wagons in this country. The gross earning capacity of a United Kingdom wagon worked out at £41 per annum—one would scarcely believe it, but such was the fact. By dividing the number of wagons running into the gross earnings for minerals and goods, that result was obtained. The rate was the quantity x, the distance travelled was also the quantity x, so that they might be called x miles and x rates. In India, 7 tons of capacity on the broad gauge did an average duty of 15,300 miles—some of them did 20,000 miles—and earned £128 per annum. The same capacity of a mètre-gauge wagon, travelling 10,600 miles, earned £90. Taking xm at 10,400 miles, the same duty would earn £87 4*s.* on the broad gauge, and £91 7*s.* per wagon on the mètre gauge; xr, the rate, was variously stated in publications of those who had tried to investigate English railway statistics at from 1¼*d.* to 1*d.* per goods ton-mile. He would put it at

1*d*., and assuming for the purpose of argument that this rate was correct, the same goods rate for the whole of India, and for all kinds of traffic, amounted to an average of 0·56*d*. per ton-mile. Applying the same rates that they had in India, and the same distances travelled in this country, an English wagon doing its 10,400 miles would earn £41. An Indian broad-gauge wagon doing the same distance at the same rate would earn £155 3*s*., or 3·8 times as much as an English wagon. A mètre-gauge wagon would earn £163 8*s*., and the proportion was nearly 4 to 1. That was all for 7 tons of carrying capacity. This enormous difference astounded him. A very great deal of attention was paid in India to the loading of the vehicles, and to their movement. The average load-capacity utilised through the whole country was 50 per cent. of the carrying capacity hauled. That was on an average a full load one way. The average dead-weights on the broad gauge for every ton of goods carried was 1·63; on the mètre gauge it was 1·61. The best was the East Indian at 1·18, and the Rajputana-Malwa Railway, 1·35. [*See page* 598.]

Mr. Thomas Parker, Jun., said, without going into details of the costs and diagrams, he would like to put forward a few practical points. He took it that the idea of the author was to introduce the wagons into this country. The objections which he himself offered to them were the turntables, the weighbridges, colliery screens, shunting operations, the distribution of the various wagons of the various railways, and the enormous number of private-owners' wagons. On the Great Central Railway there were no less than 100,000 private-owners' wagons, whereas the railway company's own stock represented somewhere about 28,000. At all the chief colliery stations it was necessary to have turntables and weighbridges, and at all the collieries they had screens of a certain size, and wagons had to be adapted to those collieries. The colliery proprietors would not go to the cost of obliging the railway company in any way, and wagons had to be made to suit them. Then there were the shunting operations in great grid-iron yards, where wagons had to be marshalled for their various destinations, which militated against the adoption of the new wagons. From his

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American experience he knew that all the points put forward in the Paper had worked in America most economically, and he had no doubt they did so in India. He thought the long wagon for carrying timber, rails, bricks, and traffic of that kind, might be used to advantage. Some had been running on the Great Central Railway, but they had been confined to the special locomotive traffic from Messrs. Beyer, Peacock and Co., and had to stand sometimes a month or two months without being used. A very important Paper was read by Mr. Lambert, the late General Manager of the Great Western Railway, before the Railway Congress in 1895, and although he went into all the figures which had been put forward that evening, the comparison was of little value owing to the great variety of circumstances prevailing upon the various railways in this country. The traffic varied considerably. There was a different condition in the North from what there was in the South. For instance, the Lancashire and Yorkshire Railway's shunting operations would take place probably over five or six miles, which also obtained in the Great Central Railway's South Yorkshire district, so that it was necessary to have wagons of a certain length to take the loads quickly, and deal with them quickly. Sometimes the loads of wagons would not exceed 2 tons, 3 tons, or 4 tons. Another important question in connection with long wagons was, that their adoption would necessitate the introduction of the continuous brake and close coupling, and it was questionable whether that was a matter to raise at all. It would be fatal to the traders of the country. They would not get the work out of their wagons, and it would necessitate the railway companies providing more station-yard accommodation. This would prevent all fly-shunting, and therefore would affect the efficiency of the work of the railways at the present time, not to speak of damage to the older stock, which would be brought about by working heavy and light together. He had looked at the four-wheeled stock arrangement, and in his opinion the overhang was too long, which would be most dangerous in shunting over the curves in a goods yard. He was very much in favour of steel underframes.

Mr. F. G. Wright wished to reply to the remark of Mr. Jones (page 578), that occasionally small items of information fell from railway officers on similar occasions to the present. As an officer of the Great Western Railway Co., he would like to say a few words. He understood Mr. Jones to say that the tare of the present four-wheeled wagon might be reduced, but in his judgment the tare had been reduced to the utmost limit, consistent with safety, especially in view of the amount of shunting to which the vehicles were subjected in the various marshalling yards. He was quite convinced that to make the wagon lighter would be to render it unsuitable for its requirements. With regard to special wagons for special traffic, it was well known that in order to keep up with the rapid pace of the present day, the mechanical engineer was straining every nerve to have machines in his workshops for doing special work. Where a large amount of repetition work was required, a great saving was effected by having machines for the purpose. He could give an instance where work costing 4*s.* 6*d.* a piece had now been reduced to 1*s.* by having proper machines to do it. He thought the same thing applied to railway vehicles. On the Great Western system, vehicles had been constructed for carrying special traffic, and whenever one of those vehicles was required there was great difficulty in obtaining it, as the wagons were nearly always at work. In the manufacture of points and crossings, for example, where it was necessary to have very often two or three wagons, by having one of proper length to take the switch, &c., it was only necessary to deal with one wagon, and that was an important item with a large amount of traffic. If only one wagon had to be brought up, loaded, and sent away, it was a great saving of time. The same thing applied to the carrying of rails; very often long rails were carried on two sets of wagons, where one set would do, if made the length required. Wagons had been designed to carry 160 chaired sleepers each, and were constantly employed running to the various points of the line; 250 twenty-ton coal wagons were now running between the Ebbw Vale and Cileby Collieries and the different parts of the system, and to have wagons running regularly carrying special traffic was advantageous and economical.

Mr. C. S. Meik said that, as his firm had been referred to by the author, he would like to say a word or two. Had his firm only known that a Paper such as that under discussion was going to be brought before the Institution they could have supplied the author with some additional information that might have been of advantage to the members in the question of coal shipment. But before dealing with that point, he would like to refer to some remarks made by Mr. Jones (page 577), who said that in his opinion the permanent way of this country was the best that could be obtained. He himself thought that was rather a bold statement to make. There was no doubt that the permanent way of this country was a good permanent way, but it was rather rash to say it was the best. Any member present who had been in America, and was acquainted with the American practice, would know that in America they hauled with their locomotives greater loads than were hauled in this country. This was due either to the permanent way, to the rolling-stock, or to the locomotives—it might be to all three; and he was inclined to think that the permanent way might have more to do with it than most engineers would allow. He did not think it was right to be too positive of anything, for he thought there was yet a great deal to be learned in this country, both with regard to the construction and working of lines for fast and heavy traffic. He had been unable to make out with any degree of accuracy what the capacity of the wagon shown in Fig. 14, Plate 78, really was. The author gave its size in tons, but he was afraid that was no guide to a railway man or to an engineer who was accustomed to deal with coal traffic. He took it, from what he could make out, that the cubic capacity of the wagon was 1,165 cubic feet, as nearly as it was possible to calculate from the illustration.

Mr. Twinberrow said the hopper-wagon was calculated for 36 tons at 43 cubic feet to the ton.

Mr. Meik said that in that case it was a fair average, and asked if the wagon would carry the 36 tons comfortably.

Mr. Twinberrow: Certainly.

Mr. Meik said the existing coal-wagons varied a great deal in size. In South Wales the 10-ton wagons now used on the Great Western Railway had 366 cubic feet capacity; that was 36½ cubic feet to the ton. A 10-ton Scotch coal-wagon of recent construction worked out at 410 cubic feet, or 41 cubic feet to the ton. If the author had calculated it at 43 cubic feet to the ton, his wagon would carry the required load with ease. He only put this question, because working it out to the scale the percentage of saving did not come to 15 per cent. If the author could gain an extra 15 per cent. of paying load in his wagons as compared with the existing 10-ton wagons, he thought he had designed a very good wagon indeed. One of the previous speakers had stated that he did not think the wagons would ever come into much use in this country, and gave his reasons. He himself ventured to think that, if they did not come into use, it would be because the railway companies were not favourable to their adoption. There could be no doubt that these high-capacity wagons would carry more coals and minerals at a lower working cost than the present small wagons, provided they could get full loads; and he did not see why they should not do so, when they were dealing with coal for shipment, or for the London market. This class of traffic did not require much shunting; once the train was made up it went to the point of shipment or to London, and could be handled without difficulty. Speaking as an engineer who had something to do with coal-shipping machinery, he did not think there would be any difficulty in dealing with these large wagons at the point of shipment; and he did not see why there should be any difficulty in dealing with them at the London centres, when they arrived there. Possibly the coal-owners would not like these large wagons to begin with, because they might have to alter their screens and colliery sidings. They would not doubtless like to do this when prices were good, but when the shoe began to pinch again, they would look with favour upon any improvement that would reduce the cost of transport. With reference to the actual tipping-machinery with which the name of his firm had been more particularly connected, the hoist given in Fig. 18, Plate 80, had been put up at Port Talbot in South

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Wales, and was one of six all of a similar type supplied by Sir William Armstrong, Whitworth and Co., for dealing with 10-ton wagons with end doors. There were other types of coal hoists made by that firm, such as the direct-acting coal hoist, which had the ram sunk in a pit underneath the cradle lifting the wagon, and tipping it in much the same way as the one shown in Fig. 17, Plate 80. There was also a hoist with two direct-acting lifting rams on both sides but above ground level, similar to what was to be seen at Barry. They all attained the same object—the lifting and tipping of the wagon, only the circumstances varied the cases in which they had to be used. The cheapest type, if the foundations were favourable, was that with the direct-acting ram underneath. Messrs. Armstrong, Whitworth and Co. were at present engaged in putting some up at Burntisland for his firm on that principle, as there the foundations were favourable, the hoist costing less than the one illustrated in the Paper. At Port Talbot the hoists were fed with wagons by a complete system of self-acting grades, similar to what was shown in Plates 81–83 in connection with Tyne Dock. At both places the wagons gravitated down to and back from the hoist or spout, as the case might be. When the author's wagons came to be employed in the coal trade, as he hoped they would be some day, the working of these grades would be rendered easier, as there was no doubt this type of wagon would run much easier than the existing four-wheeled type did. [*See page* 607.]

Mr. T. Parker, Jun., said he did not think he questioned the advantages of the wagons at all. He quite agreed that the large capacity of the wagons would be an advantage. What he said was, that they were not applicable to the working of the lines in this country. There was one other point which he left out with regard to the warehouses where the goods were stored. The goods had to be lifted into the warehouses by hoists, and were often lifted two or three or more floors for storage purposes.

Mr. John A. F. Aspinall, Vice-President, said it had occurred to him, during the reading of the Paper, that one of the great points in connection with private-wagon ownership had practically not been dealt with, though the number of wagons which were owned by the different private-wagon owners, colliery companies and others, was referred to by one of the speakers. He thought he was right in saying that in the evidence which had been given before the recent Royal Commission which dealt with railway accidents, it would be found that the number of wagons owned by people outside the railway companies was stated to be about 500,000. In England and Wales there were altogether about 667,000 owned by the railway companies, so that it would be seen how large a proportion of the wagons run upon the railways were owned by others than the companies. Any proposition, therefore, for altering those wagons in the slightest degree touched a very large number of people. Of course the wagons were owned, some in small numbers by small traders, and some in large numbers by collieries. He considered it to be an unfortunate thing that private-wagon ownership ever took root in this country. It could not be a good thing for the trade of the country that 500,000 wagons, weighing probably 6 tons each, taking the heavy and the light together, should be moved during one journey empty, and a dead-weight of about 3,000,000 tons be hauled over the country. Any change in the direction of economy would seem to be one which led to the use of those wagons which now went back from their point of delivery empty. There were immense difficulties, and for certain railways—such railways as the Taff Vale or the Barry—there was no load to bring back, and there it could not be helped; but he thought their American friends would be found to make use of their rolling stock to a very much greater extent than was done in this country in that particular way. There was one notable instance in this country, where a railway company acquired a very large number of colliery wagons which they found in the collieries near their system. How they considered that to have succeded, they could tell if they elected to do so. But it was not only a question of hauling the empty stock back to the collieries; it was also a question of sorting out, marshalling, and re-arranging the wagons that belonged to hundreds of different owners, and

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delivering them to the colliery from which they originally came. That represented a tremendous annual loss.

With regard to the form of wagon which the author suggested for carrying coal to the port, he hardly thought that that hopper-wagon or any form of hopper-wagon was the one which ought to be looked forward to as being the best, because it was obviously impossible to load other goods than coal or minerals into a wagon of that form. But it was true that long wagons were used by the Americans, and the author in his Paper showed some wagons upon a tip which had been turned bodily over in order to get rid of the coal, Fig. 24, Plate 84. There were some objections to that method. Naturally when a wagon was turned over the oil would run out of the axle-boxes; but a more serious objection was that the total weight of the wagon was thrown on to the sides, the thin sides which were never intended to carry the whole weight, and it must require some special construction in order to make them withstand the excessively hard work to which they would be put. He had not seen that particular form of tip, but it had always struck him as a difficulty, that the body of the wagon would not be strong enough to bear the weight. With regard to coal-tips, he thought he was right in saying, that there was probably not a single coal-tip in this country at any of the ports which would take a long wagon. Therefore it followed that the people who controlled the question of the carrying of coal in those large wagons were the colliery companies on the one hand and the port authorities who owned the coal-tips on the other, and that the railway companies only came into it as intermediaries. If the author could persuade the colliery companies to alter their wagons, the dock companies to alter their machinery, and put on wagons and machinery which would carry and deal with greater loads, he should be only too glad to see it. There was no difficulty about working them with coal for shipment; but in dealing with coal which was sent in thousands of wagons every day to stations for sale by the different traders, it became a very different question, because the coal was taken out of the wagons slowly. The small colliery proprietor or wagon owner said: "If you have a wagon which carries 30 tons, I have to keep that wagon standing the whole time until I can empty it, and I can only do that perhaps in a week. If that wagon is split up into three parts and is made into the present English ordinary wagons of 10 tons each, obviously when I unload the first 10 tons, I can send one-third of my rolling-stock back to the colliery and get it loaded, and that part of my capital is earning money." On that account the wagon owner did not like the long wagon. That was a difficulty he was afraid the author would never meet, and was one not found in other countries because they did not deal with their coal in the same way.

It was suggested that large coal-stores should be placed at the larger stations, but that difficulty became a very great one when it was remembered in how many hands the sale of coal rested at present. It would also involve a large capital expenditure on the part of some one, upon which he doubted very much whether even a very small interest would be seen. If it were true that there were 500,000 wagons belonging to traders which ought to be altered—he would take it for granted they ought to be altered—it should be remembered that a wagon had a life of about twenty-five years, which meant that these must be replaced at the rate of 20,000 per annum for twenty-five years to get them altered—at any rate it would take a very considerable time. He quite sympathised with the author's views upon the question of carrying coal in the large wagons, but it was a mistake to suppose that the question rested with the railway companies—it rested really with the collieries and the dock owners.

With regard to the question of the haulage of heavier trains, which the author had lightly touched upon, he would point out that the Lancashire and Yorkshire Railway had early this year commenced to haul coal trains consisting of sixty wagons, giving a gross load behind the engine of 1,000 tons, 600 tons of which was coal, 400 tons being the weight of the wagons. The eight-wheeled coupled engines which did this work returned from the port to the collieries with 100 empty wagons.

Mr. Twinberrow in replying thanked Mr. Wainwright for his appreciative remarks (page 576), and was pleased to note that he

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preferred the advantages offered by steel as a constructive material. Referring to the damage suffered by rough shunting, there was one point he thought that was overlooked sometimes, namely, that the heavier the mass of the wagon the greater the inertia and the less the shock which would be communicated through that wagon to adjacent vehicles, or from that wagon to the running gear beneath it. The resistance to buffing shock was merely the inertia of the body, and its capability of absorbing a shock with small acceleration. A light body would be much more likely to damage the wheels, axle-boxes, and so on underneath it, than a heavy vehicle. With reference to the resistance of friction plates, he quite recognised that by placing the weights of the wagon upon friction plates which were displaced from the centre, the moment of the friction causing an obstruction to the free setting of the bogie was greater, but he did not think it was so much greater as to occasion any fear of inconvenience. The practice of the Northern of France Railway, which was running what he thought might be termed the finest express engines in the world, was to carry the whole weight of the front end of the engines on rubbing pieces, which were placed immediately under the main frames; and as far as he could gather, the running of those engines was equal, if not superior, to anything else that had so far been reached.

With respect to an equalising buffer, he had seen several examples, but as far as he knew, the one he had designed in connection with the wagon was the first that combined what might be called equalising and compensating, Fig. 25, Plate 84. An ordinary equalising-buffer played in guides, and therefore did not compensate for the amount of lateral throw-over that vehicles of different lengths gave to their headstocks, and so caused buffers to overlap and lock. His design was so arranged that the buffers would meet those of a given standard vehicle on any curve. There was an angular as well as a reciprocating motion, and that had enabled him to fit automatic couplings, because automatic couplings fitted to buffer-heads of that kind could always be depended upon to meet one another line and line, and not to throw over to the extent of missing the coupling. He did not think Mr. Wainwright need have any fear of fouling fixed structures. Round a very sharp curve the long body of the wagon would be drawn in as a chord to the curve, and in all the designs he had kept well within the minimum load gauge of English railways.

With respect to Mr. Jones's observations, he thought the remark made by Mr. Meik on the real and nominal capacity would also apply to some Indian stock (page 584). He fancied that the custom was sometimes adopted of putting axles under a vehicle which would carry a certain load, from which the permissible net load was determined; thus a wagon might be nominally capable of carrying 20 tons, whereas the capacity of the body might be equal only to 11 tons of coal. He knew that some of the Indian wagons would have to be loaded very considerably above the curb before they would carry their nominal load of coal. With freight in bags the load could be piled up to a certain extent. On the nitrate railways in Chili, which were of a narrow gauge, they had a very good ratio of load to tare, when carrying their bag nitrate down to the port; but when carrying coal back to the nitrate fields, wagons nominally of 20 tons capacity and weighing about 5½ tons would only carry 5 tons of coal. Therefore in comparing stock it was well to bear in mind that it was not merely what the springs and axles were calculated for, but what freight in practice could be loaded into the body. With reference to Mr. Jones's estimate that there was a possible saving, supposing the tare was reduced in the ratio claimed in the Paper, of 3½ millions of money (page 579), he had confined himself to the mineral traffic, and had estimated a saving of about 2¼ to 2½ millions in the mineral traffic of the country. But Mr. Jones's remarks were much to the point as to the way in which the English railway returns were kept. It was an old story, which had received very vigorous criticism in an article in the "Edinburgh Review" in 1876, and it had remained the same ever since. But possibly if one continued to hammer away for another quarter of a century there might be a difference. That was the one distinctive feature that had separated the railway returns of the Continent of Europe and America from English railway returns. Whereas in this country the expenses were calculated by the train-mile, and no

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particulars were returned of the goods except the actual weight carried, the other companies recognised that the ton-mile was the indispensable unit, and the ton-mile was therefore the basis of their costs. By that means they at once saw that increase of capacity was the best and most logical means of increasing the ratio of gross earnings to working expenses. Mr. Jones said that no improvement was possible in locomotives, but that statement should be qualified. As far as the economical result of English locomotive working went, there was the greatest room for improvement by increasing the hauling power; and although the load-gauge was a hindrance, Mr. Aspinall had shown (page 589) that without any extraordinary means he could put a boiler on to his express engines, which had an increase of something like 70 per cent. over what was a few years ago the standard practice, and he believed he was also doing something similar in the matter of goods engines. He had hoped Mr. Aspinall would have mentioned a few results as to the working of the eight-coupled engines on the Lancashire and Yorkshire Railway. There was no doubt that, combined with an increase in the capacity of the rolling stock, there was also a very great opening for an increase in the capacity of the locomotives; and though there were difficulties in the way, they were not insuperable. He did not know whether Mr. Parker considered his statements were arguments against the introduction of high-capacity rolling stock (page 586). He quite agreed with him that the difficulties he mentioned were very great, but it was astounding that English engineers at the present day should say that a class of plant, having been in use for half a century, must therefore be continued. There were turntables, hoists, lifts, and a system of working traffic that had been used while railways had been in England, and therefore they must be used so long as railways were in England! But he knew it was perfectly absurd for any one department to say that a thing was wrong, and it was going to change it. It could not be done in any such way. It could only be done by unity amongst the different departments, and of course instructions for that must come from head quarters. He did not think he was betraying any confidence when he said that in a certain district of England the engineers of the harbours and docks, whom Mr. Aspinall looked upon as such obstructionists, were meeting, or about to meet, the representatives of the railways, in order to ascertain exactly what it would cost to move those obstructions. An engineer wanted to know the size of his difficulties; let him measure them up, estimate the cost of removing them, and the probable advantage he would get when they were removed.

With respect to continuous brakes, English railway engineers seemed to look upon continuous brakes on freight trains as a sort of luxury which was quite beyond them. The day was past when a company could afford to stop its trains in order to put the brake on. The facility in working traffic, which continuous brakes would give, would in his opinion pay for the cost of the brakes over and over again, although possibly not if each separate 10-ton wagon had to be equipped. The cost of the equipment for a 40-ton wagon would hardly exceed that for a 10-ton wagon; he could equip four units of tonnage for the cost at which English railways would equip one. Therefore if English railways were to maintain anything like a foremost place in railway working, and take advantage of the most recent developments, and in fact keep their traffic working in any other way than by duplicating and quadruplicating their roads and sidings, they must go in for continuous brakes, automatic couplings, and other improvements which would necessitate the introduction of large wagons.

He was very pleased to hear the remarks made by Mr. Wright of the Great Western Railway (page 583). That company liked a good thing, and generally got it. Some might be disposed to think that they did not study the cost sufficiently, and that nothing seemed too expensive for them; but of course that was not the concern of anyone outside. He was pleased also to hear Mr. Meik's remarks (page 584), as he looked upon him as one of the foremost harbour engineers, and they were gentlemen whose assistance must be obtained if the movement was to go on. But with regard to Mr. Parker's reference to the hoists (page 586), the question of existing plant was a matter which could be put down in a simple black and white statement; and he did not think that was going to be an

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unanswerable argument. Machinery was not a natural law. One could alter machinery, though powerless to interfere with natural laws. Mr. Aspinall's remarks might appear rather discouraging, but he was confident that among the directorates of railways a more active movement would be seen in the future with respect to the introduction of the stock.

With reference to the return of empty wagons, a good deal of time could be wasted on what looked to be a very nice argument in theory. It should however be remembered that England was a mineral country, and that about 3 tons of coal and other minerals were shifted for every ton of ordinary freight. Even supposing that the collieries absorbed all the ordinary freight, there was only 1 ton to send back to the colliery district for 3 tons taken away from it. Generally speaking, for facilitating traffic it would be found that a certain amount of division of stock, especially stock for special districts, was preferable to trying to pool the whole business. With regard to the provision of depôts for private traders, that question had been solved in the north-east of England, but the practice of certain railways was sometimes strange to neighbouring lines. They termed railways outside their system "foreign roads"; they were foreign indeed because one railway seemed to be as hostile to its neighbour as two States at daggers drawn. In the north-eastern district of England they were not troubled with private owners; the North Eastern Railway had been too strong. That railway used hopper-wagons throughout for the mineral traffic, but every station had depôts which would hold three or four truck-loads; these depôts consisted simply of concrete or masonry walls, with a pair of timber baulks on the top and a short incline. Each stall was taken by a trader, who generally had his name above on a small board. The wagons discharged their load, and if necessary the engine that brought them up could take the empties away. That was done on a small scale, and why not on a large scale? It might be thought that he was minimising the difficulties. He knew the difficulties were great, but difficulties had never occurred to him as a reason for cessation of efforts; and in a big question like that, combination was required and the movement could only be forwarded by such combination. With reference to the tipping over of the wagon to empty it, Mr. Aspinall rather objected to discharging the coal through the bottom or by rolling the wagon over. He quite agreed that rolling the big wagon over was not for its good. He thought that self-discharge, owing to the cheapness of plant needed, the ease of the process, and the natural law which it seemed to follow out, would insure its wide adoption in the future, particularly when it was borne in mind that for a mineral country it was a physical impossibility to get anything like a satisfactory back-load. What was wanted was to get the empties back as quickly as possible, and to get them up again with a full load. He was very gratified by the manner in which the Paper had been received, and his remarks listened to. The subject was a difficult one that could not be fully presented in the course of a few months' work; but he had been devoting a considerable amount of time to it, and it was a great reward to him to find that he had succeeded in interesting the members present.

The President in closing the discussion hoped that written communications would be added. That was a feature which had been growing in the last two or three years, and might be usefully extended. The author of course would have the right to reply to any written communication. When the Paper came to be published, its value might thus be enhanced, and the author would have additional reason for thinking his time had been well bestowed in preparing for the Institution his very interesting communication.

Communications.

(See Plates 85 and 86.)

Mr. T. W. Barber wrote that he would like to know the author's opinion on the question of the adaptation of continuous brakes to goods trains. The adoption of a new type of wagon would seem to offer an opportunity for a move in this direction. Was there any other difficulty to be encountered, beyond the consideration of first cost? The swinging frame and draw hook, shown on Plate 78, would

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seem to place difficulties in the way of automatic coupling, since approximate alignment was essential, and would not always occur with such an arrangement. This difficulty, it was presumed, would be accentuated in the case of a train made up of long and short vehicles.

Mr. JAMES T. JEPSON wrote that he thought the Paper was most interesting, and one which deserved very careful consideration by all concerned. He agreed with the author that a greater saving in the cost of transport could be effected in the dead weight of mineral trains by the use of high-capacity bogie-wagons than in any other direction. He did not, however, think that the type of bogie-truck without centre pivots, as suggested by the author, would be satisfactory, when continuous brakes were used, which would be most likely with these wagons. When the brake was applied, it was through the bogies that the wagons with their full loads would have to be brought to rest, often in a very short space; and when a train was composed of other vehicles that were not fitted with the brake, but had train pipes, the wagons so fitted would have to bring others to rest; consequently there would be a heavy thrust on the centre pivots and pins, and without these the wagon might leave the bogies. It would therefore be necessary in his opinion to have centre pivots.

He thought the author's high-capacity four-wheeled wagons mounted on cantilever-extension trucks were complicated, and could not effect the same saving in tare and train length as the bogie-wagons, which latter he believed would prove the most suitable and economical for minerals in bulk, such as coal and iron. They could be brought into immediate use in carrying minerals from the mines to the various engineering and iron works, without serious alteration to existing plant, and by the railway companies themselves for the conveyance of locomotive coal from the collieries to the various coaling stations; but for both these purposes the box-wagon would be more suitable than the hopper type. In this service the railway companies could readily give the bogie-wagons a trial, and effect a great saving in haulage without alteration to terminal plant. The present four-wheeled wagons used for locomotive coal could be transferred for ordinary traffic. The Leeds Forge Co. had two 30-ton all-steel bogie-wagons at present carrying coal from the New Hemsworth Pits near Doncaster to their works in Leeds. These wagons, shown in Figs. 26 and 27, Plate 85, were of the box type, and measured 40 feet by 7 feet 7 inches by 4 feet inside, which gave a net capacity of 1,214 cubic feet, length over buffers 43 feet, and tare 13 tons 16 cwt. They were arranged for discharging over coal drops, and for this purpose were provided with four large bottom-doors, each opening measuring 4 feet 6 inches by 2 feet 1 inch in the clear, and what remained of the 30 tons after these doors had been dropped was regularly cleared by five men in 15 minutes, so that the discharging was done at very little cost. The wagons were also provided with an opening on each side 6 feet 9 inches by 3 feet in the clear, and one end opening the full depth of the wagon; these side and end doors were however not intended for regular use, but simply for convenience should necessity arise.

By comparing these wagons with the ordinary four-wheeled 8-ton wagons as used by the Midland Railway, it would be seen that there was a saving of 33 per cent. in the tare, which was effected on the double journey, and 40 per cent. in the train length, in favour of the all-steel bogie-wagon. The tare of the four-wheeled wagon was from 5 to 5¼ tons; it measured 18 feet over buffers, and had a capacity of 300 cubic feet. It would take slightly more than four of these wagons to carry the same amount of coal as the bogie-wagon; then the total tare would be 20 to 21 tons, and the length over buffers 72 feet, as compared with 13 tons 16 cwt. and 43 feet for the bogie-wagon.

A saving of 40 per cent. in train length or siding accommodation was a great consideration in or near large towns, where land was costly, and was a large item in works where siding accommodation was limited. No difficulty had been experienced with these wagons in traffic; they would travel round the sharpest curves much more easily than the four-wheeled wagons, and were regularly being shunted round a curve of 80 feet radius. One wagon had been in use on the Lancashire Derbyshire and East Coast Railway about

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twelve months, running regularly in trains with four-wheeled wagons between Tuxford and the various collieries in the district; and from information received it had answered its purpose well. Such wagons were constructed with pressed-steel underframes, bogies, and doors, and might be seen at any time in traffic between Leeds and Doncaster.

The writer had lately designed a similar wagon, arranged with two openings on each side in addition to the bottom doors, having the length over headstocks reduced to 35 feet, and over buffers to 37 feet 10 inches; at the same time the capacity of 1,200 cubic feet was maintained. The tare of this wagon would not exceed 13 tons; thus the respective saving in tare and train length over the 8-ton wagons would be 37 and 47½ per cent. His firm (Leeds Forge Co.) had also a self-discharging all-steel bogie hopper-wagon. The bogie-wagons referred to above had double the capacity of London and North Western and Great Western so-called 20-ton steel wagons, referred to by the author in his Paper, and consequently showed a considerable saving in tare and train length, even when compared with these latest types of high-capacity four-wheeled wagons.

Mr. W. R. S. Jones, in continuation of his remarks at the meeting (page 577), wrote that, with reference to the designs submitted by the author, he agreed with Mr. Wainwright (page 576) in thinking that axles of 14 tons load-capacity were heavier than necessary to obtain good results in the proportions of tare to load. In Indian practice, where the maximum wheel-loads per pair were limited to 12 tons on the 5 feet 6 inches gauge, and 6 tons on the mètre gauge, identical results were obtained, both in four-wheeled and bogie goods-vehicles, when iron or steel was used in their construction. The author claimed for the latter superior advantages in lightness, out of agreement with his own experience. Where the designs were not dominated by unduly heavy buffer-gear and other items, the results were as he had himself already stated. In his experience the most that could be claimed for bogie vehicles was that they were steadier, lighter in haulage (according to his dynamometrical experiments), kinder to the roads and themselves, cheaper in repairs, and they occupied less space, to the extent of that occupied by one set of buffers per vehicle. The results obtained in his own recent practice had been as follows:—

Platform goods vehicles, both bogie and four-wheeled	Carry 3·8 times their own weight.
Covered goods vehicles and high-sided wagons, bogie and four-wheeled .	" 3 " " " "

If the vehicles of the 5 feet 6 inches gauge substituted wheels of 3 feet in diameter, with tyres 2 inches thick, for those of 3 feet 7 inches diameter, with tyres 2½ inches thick, then exactly the same proportion obtained. The latter vehicles withstood shunting shocks, where much larger engines and heavier loaded vehicles were in daily use, better than those employed on British railways. His experience on the Rajputana-Malwa Railway with bogie goods-vehicles of high carrying-capacity was that they sometimes crippled the old buffer and draw-gear springs of the older wagons, and all had to be gradually strengthened up to meet this new condition.

His experience of short wheel-bases and long bodies, when the latter were 21 feet 6 inches and the former 10 feet, was that at speeds similar to British railway goods-speeds they were extremely unsteady, and were liable to be unevenly loaded. He also agreed with Mr. Wainwright in his remarks regarding the departure from well-tried bogie practice, in respect to the connections between the bogie trucks and the body of the author's large wagon. An actual example would best explain his objections to the author's arrangement, namely, the flat bogie-wagon illustrated on Fig. 28, Plate 85, yielded vertically to every inequality of the road, such, for instance, as the tortuous entry of the outer rail of a sharp curve; with this type of wagon, out of about 1,000 in running he had never known an instance of derailment, whilst the type illustrated in Fig. 29, Plate 86, derailed on sharp curves directly it was put into running. Both had a slight clearance between the side sliding-blocks of bogie and body. On investigation the reason was obvious; the flat wagon was vertically pliable, the covered wagon was not. The lower bearing-blocks were removed, and others

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having pads of india-rubber under them effectually cured the defect.

With regard to the body of the author's wagon, it appeared to him that the small discharge-doors dominated the whole design adversely, as regards the cubical capacity; in short, there was an unnecessary amount of hopper. If he might venture to suggest an excellent example of treatment of discharge-doors needing the minimum of hopper, he would refer to the example illustrated in Fig. 30, Plate 86.* By the substitution of this arrangement for that employed by the author, the length of his wagon might be shortened by at least 10 feet without loss of capacity.

With regard to the substitution of iron or steel for timber in the construction of vehicle stock generally, Mr. Gibson, the late carriage and wagon superintendent of the Great Western Railway, used it largely for both goods and coaching vehicles over forty years ago. Beyond its superior strength and lightness, the outside dimensions of the vehicle body, including the floor, were practically all load capacity. The author alluded to the many obstacles to the introduction of his large wagon, and suggested a reduction of rates as an inducement to traders to join the railways in the use of them. The traders occupied a position intolerable to themselves and certainly to the railways, brought about in the first instance by the poverty of the railways. It would therefore be unfair to make these demands from them ; the ownership and control of vehicles should both be in the hands of the railway companies.

Without however interfering with any existing arrangements in regard to screens, weighbridges, turntables, shipping-staithes, etc., wagons on four wheels, occupying the same line space, wheelbase, and outside dimensions (including projections), if built in steel could be made to carry from 40 to 60 per cent. more load and tare less than at present, while by adding a foot to the length of a trader's wagon it would carry 75 per cent. more load. In all this there was no need for wheel-loads exceeding 10½ to 11 tons per pair.

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* For further particulars see Voss's "Railway Car Construction," page 54.

Although there were many obstacles to the universal adoption of bogie goods and mineral vehicles, there still remained a field in which large numbers of them might be usefully employed. But the substitution of iron or steel for timber in the construction of any kind of goods and mineral vehicles effected a marked improvement all round, even within the obligatory dimensions imposed by the existing circumstances named by the author and others; as by a simple example he would endeavour to establish in a cursory view of the situation. The data he would employ might be imperfect, but it might be taken as approximate for the purpose aimed at, namely to indicate the very great advantages following better practice in vehicle stock. According to the author, the Board of Trade returns showed that the increase of goods and mineral traffic amounted to 27·5 per cent. and 28 per cent. respectively in a decade; say 28 per cent. all round. But the period it would take to replace entirely the present system for a better one would be the average life of a wagon, or two decades; whence the increase would demand an increase of vehicles, locomotive power, sidings, workshops, running sheds, station machinery, etc., of 28 per cent. × 2 = 56 per cent. in twenty years.

He would roughly take the following as fairly representative of the average of a goods and mineral wagon:—carrying capacity 8 tons, tare 6 tons, length 18·75 feet (whence 281 of them would stand in a mile), cost £75; cost per ton of tare £12·5, and per ton of capacity £9·375.

Mr. Aspinall (page 587) gave as the number of goods and mineral wagons:—Railway wagons 667,000, traders' wagons 500,000 = 1,167,000 total.

From the data already given, the following totals are derived:—carrying capacity, 9·336 million tons, tare or dead weight, 7·002 million tons, cost £87·525 millions; of which the railway contributed £50·025 millions and the traders £37·5 millions. The end-to-end standing room 4,153 miles, and the total gross tonnage 16·338 million tons.

At the end of twenty years these totals in millions would be increased by 56 per cent.; whence the grand totals in *millions*

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would be:—carrying capacity, 14·564 tons, tare weight, 10·92 tons, gross tonnage 25·484, cost £136·5; railway share of cost £78·2, traders' share of cost, £58·3. End-to-end space occupied 6,475 miles, number of wagons = 1,820,500.

New Practice in Iron or Steel.—As a new basis he would take a vehicle that should have the same wheel-base and extreme height from the surface of the rails, but 1 foot longer, than a North Eastern Railway coal wagon of 10½ tons capacity, assuming that a wagon of these dimensions would not foul any existing structure or appliance. Such a wagon mounted on a steel underframe within the above limits would measure 17·5 feet × 7·75 feet × 4·5 feet = 610 cubic feet capacity; which at 40 cubic feet per ton would equal 15·2 tons of coal-carrying capacity. This wagon would measure over the buffers 20·5 feet; whence 275·5 wagons would cover a mile. In existing practice the nearest analogue to such a vehicle that the writer could call to mind was an East Indian Railway iron coal-wagon, weighing 7 tons, carrying 17 tons, mounted on wheels 3 feet 7 inches diameter (having tyres 2½ inches thick and weighing 2 tons per set of 4 wheels and 2 axles), which cost erected in India £138·6; whence the cost per ton of tare weight equalled £19·8. But this rate included, besides manufacturers' profits, packing, carriage to port, loading, freight, insurance, landing and forwarding charges, which together usually worked out to £2 per ton. The cost in England would therefore be about £18 per ton of tare. Also if this wagon were mounted on 3-feet wheels, it would weigh half a ton less, and carry the same amount more; or capacity 17·5 tons and tare 6·5 tons; whence the tare of a similar wagon of 15 tons capacity would be $\frac{15 \times 6 \cdot 5}{17} = 5 \cdot 7$ tons, and the cost would be £102·6—whence also the cost of carrying capacity would work out to £6·84. Say £7 per ton.

For the total carrying-capacity tonnage required twenty years hence, namely 14·564 million tons, the other totals would be in *millions*:—tare weight 5·53, gross tonnage 20·1, cost £99·6; the number of wagons 970,933, mileage occupied = 3,517 miles. Whence the cost to railways would be £57 millions and the cost to traders £42·6 millions.

Collated, these results were as follows :—

	Present.	Future, including additions of 56 per cent.		Difference between Old and New.
		Old practice.	New practice.	
Number of vehicles, millions	1·167	1·8205	0·970,933	0·849,567
Total carrying capacity . million tons	9·336	14·564	14·564	Nil
Total tare or dead weight ,, ,,	7·002	10·92	5·53	5·39
Total gross weight . ,, ,,	16·33	25·48	20·1	5·38*
Total cost . . million £	87·5	136·5	99·6	36·9
Cost to railways . ,, £	50·0	78·2	57·0	21·2
,, ,, traders . . ,, £	37·5	58·3	42·6	15·7
End to end space occupied by vehicles . . miles	4,153	6,475	3,517	2,958

* Represents difference in gross haulage in locomotive power from 56 per cent.—thus $\frac{5\cdot38\times100}{25\cdot48}=21$ per cent., whence the extra locomotive power required would be reduced from 56 per cent. to 21 per cent.

The goods and mineral locomotive power utilized in 1899 was represented by the author to be 177 million train-miles at say 10*d.* per train-mile, whence the locomotive expenses alone cost £7·33 millions per annum. Thus the extra locomotive power in twenty years would gradually increase from zero to 56 per cent. = £4·1 millions at the last year. The annual increment would thus be £0·366 million per annum, whence the sum of the total for twenty years would be :—

$$\frac{20\,(20-1)\,0\cdot366}{2} = £69\cdot54 \text{ millions.}$$

But by the new practice 35 per cent. of the above sum would be saved, or $\frac{£69\cdot54\times35}{56} = £43\cdot46$ millions.

The total value of the traders' wagons in this country did not appear to exceed 3½ per cent. on the total railway capital; he therefore could not understand why this small sum should be allowed so long to dominate the operations of the railways in the

(Mr. W. R. S. Jones.)

adverse manner depicted by Mr. Aspinall. In their mutual interests it would appear to be but reasonable action on the part of the railways to unite and emancipate themselves from what appeared to be an almost intolerable position. Amongst other very large collateral advantages, the adoption of even the limited better practice suggested in the above cursory investigation would, in the period of renewals and additions, and without interfering with the usual procedure, clear off this incubus with a profit to the railways, and also afford desirable relief to the traders. If however the railways continued on the same lines as at present in rebuilding and making the necessary additions for increase of traffic, they would in twenty years expend £78·2 millions, and add all round 56 per cent. of capital in many other directions. But if they adopted the new practice suggested, the same work could be done for £57 millions; also by the latter practice the extra locomotive power would be reduced from 56 per cent. to 21 per cent. The difference in cost of locomotive power during a period of twenty years was shown to be £43·46 millions. Thus these two items alone amounted to £121·66 millions. But the total value of all the capacity required conjointly by the railways and traders, by adopting the better practice, only amounted to £99·6 millions, whence the railways would emerge from the transaction with a profit of £22 millions.

Another very important point gained would be that the increased capacity would actually occupy less siding-room by $\frac{(4{,}153-3517)\,100}{4{,}153} = 15\cdot3$ per cent. than at present, which also meant that the present sidings, etc., would suffice for twenty-five years hence. Finally, besides the £22 millions named above, there were:—

Cost of extra locomotive engines, workshops, running sheds, and appliances . .	35 per cent.
Cost of sidings, storage ground, approaches, and their maintenance . . .	56 per cent.

of which the total value would doubtless be enormous.

Mr. Cree Maitland wrote that he thought the sliding doors under the hopper-wagon would be liable to be choked, and become unworkable through distortion of plates and gear resulting from rough usage, and the parts would be difficult of access. Doors of iron low sides were notorious for the way the sides buckled and the difficulties encountered in closing them.

The friction of spring plates, relied on to damp out fore and aft motion (page 565), would be soon lost in actual practice, and the tendency to such motion would be increased, and the wagon tend to lift, in shunting and stopping ; more especially, if contents of the wagon shifted in transit, and moved to one end or the other to any extent, as a result of careless loading. Frames of pressed-steel plate, on the cantilever extension principle, would be liable to get out of square, but cast steel, if sufficient reduction in weight could be attained, would give greater rigidity.

With reference to reduction of tare (page 562), it would be interesting to know the weight of frames complete, Figs. 9 and 10, Plate 76, (without wheels, axles, springs, and brake gear), and also similar information with regard to the cast-steel frame, Plate 79, in order that they might be compared with recent practice in America, where they were now making a cast-steel " pedestal " bogie or truck (central pivot) to suit any type of wagon, with cast-on side bearings of malleable iron. The weight for a 40-ton (2,240) capacity car was 1,500 lbs. per bogie, and with bolster at 550 lbs. the total was 2,050 lbs., or with two bogies to the car 4,100 lbs. for 40-ton car. These steel bogies stood a breaking load of 65,000 to 70,000 lbs., and were said to be lighter and 20 per cent. stronger than built-up or pressed-steel frames. The above weights were for the frames and bolsters alone.

Mr. A. Woodroffe Manton wrote that the diagrams, Figs. 1–8, (pages 559–560), were certainly instructive, and it would be interesting to note the corresponding United States diagrams, where high-capacity cars, whose ratio of load to loaded-car weight varied from 73¾ per cent. to 79 per cent. for flat cars, had been in use some time, and where conditions were admittedly different. If the United States

(Mr. A. Woodroffe Manton.)

railway companies could afford to replace 30-ton (U.S.A. ton) wood cars with a 66½ per cent. ratio with the 50-ton (64-ton gross) steel car with 74½ per cent. ratio, he thought it would be good practice to replace the English wood greased-journal wagons, with their ratio of 61 per cent., given by the author. Fig. 8 showed how little the English had improved in their freight-handling methods, even with the large capital expenditure on stations and extra permanent way. A graphic comparison of first cost and maintenance disbursements for new merchandise and mineral stock with each year's ton-miles, here and in the United States, would be useful; and he agreed with the author in condemning the term "train-mile."

He would also like to know the relative figures (1) for first cost per ton of capacity; (2) for cost of *ordinary* upkeep per ton; (3) for cost of *extraordinary* maintenance and renewals (due to collisions, &c.) per ton for high capacity, (*a*) merchandise cars, (*b*) mineral cars, (*c*) ordinary English merchandise wagons, and (*d*) ordinary English standard coal and ore trucks. He would be glad if the author could give any figures as to relative amounts of small freight-loads on branch lines, and the actual amount of junction-transhipment practised.

It would be admitted, he thought, that the high-capacity merchandise cars were lacking in sufficient side-web doors for *cheap* unloading; and in regard to the long wagons (page 564), he feared that buffer-locking trouble would arise. He thought that larger, even if unequal sized, bogie-wheels should be introduced in the author's hopper design; the centre of gravity seemed rather high. Central buffers and couplers would, he presumed, be the final design. He would like to know whether the author had tried 8-wheel (as some long London and North Western coaches) cars, with outer axles fixed, and inner radial, in place of bogies, such as Fig. 16, Plate 79, which appeared to have few advantages, and whether axles with one wheel rotating loose on a bush on alternate sides of car, to cancel resistance due to serious circumferential dragging on curves (and during swaying) had been tried. It would be interesting to note revolution differences, and comparative dynamometer results behind a locomotive, and to notice reduced wear.

With reference to demurrage (page 571), he thought the reduced number of cars, and types of cars, would help this vexed matter, so often the railway company's own fault.

On the question of coal-tipping plant, it seemed unfortunate, when shipping delays were serious, and where so much ingenuity had been displayed in the design of tips and staiths, to perpetuate the use of the present antique and heavy wood-wagon practice. Much economy of time, labour, and water, would result from the use of high-capacity cars (hoppers, or plain). A commission might with advantage settle standard dimensions, so that the plain car could run into a long cradle, turning on end-bearings, or other simple arrangement. This would obviate expensive hoppers.

In the designs of the plates the writer suggested putting web-stiffeners *inside* to reduce air-resistance. Were the cars of the maximum gauge width? He did not notice that the much-exaggerated value of coupling slack (assisting the locomotive) in English practice was dealt with in the Paper, and he would like to know the author's views on the question. He would lay stress on the reduction of types. If one wished to load long timber or machinery (even when compact) over 7 or 8 tons, one must specially order and wait for timber-trucks or "crocodiles." Expensive formation widenings would be deferred, receipts per track-mile much increased, and time saved, if continuous breaks were fitted to all cars, giving signalmen more confidence in "sandwiching" between fast traffic without side-tracking.

He trusted this valuable Paper would assist in bringing this question of scrapping their designs for old-fashioned stock as an important factor in future railway economy at this time of increasing expenditure-earnings ratio.

Mr. C. S. Meik, in continuation of his remarks at the Meeting (page 584), wrote that he could quite understand that, on those railways where the mineral traffic was carried on in wagons belonging to the traders, the difficulty of introducing high-capacity wagons might be serious, but he could not see why companies owning the rolling-stock used for the carriage of minerals over their

(Mr. C. S. Meik.)

lines should not build new stock on the lines proposed by the author. As regards the carriage of coal for shipment, with which the writer was principally concerned, it appeared to him that of the parties interested—the railway companies, the colliery owners, and the dock owners—the key of the situation rested with the first named. Should the railway companies arrange to use large wagons and offer the colliery owners sufficient inducements to alter their screens and sidings to accommodate them, in the shape of more favourable rates and quicker despatch—and this they could afford to do, seeing that working expenses would be reduced by the adoption of the larger wagons—then the dock owners would have no option but to provide suitable appliances for dealing with the wagons at the port of shipment.

In his opinion the present was a particularly favourable time for a change in the method of dealing with coal intended for shipment. More than one large port is in the coming session applying to Parliament for powers to provide extra dock accommodation for large vessels. He might instance Swansea, Newport, Bristol, Grimsby, Garston (London and North Western Railway); while several ports had large docks under construction or about to be commenced, such as Cardiff, Hull, the Clyde, Grangemouth, Leith, and Workington. At all of these places there should be no difficulty in erecting machinery suitable for dealing with wagons each carrying from 30 to 40 tons of coal.

He looked forward to the time when all mineral traffic and a large part of the goods traffic between the chief centres of trade would be carried in large wagons fitted with bogie trucks, automatic couplers, and the automatic brake.

Mr. James Steele wrote that he thought the Paper had been prepared at a most opportune time, as the question of larger capacity wagons than those at present employed was and had been much discussed by traders and others interested in the question. The private owner or trader was at present limited to a wagon of 10 tons carrying capacity; and unfortunately the question of the tare of this 10-ton wagon, so far as the trader was concerned, was generally increased much more than it ought to be, because the trader exacted from the wagon-builder the maximum of size and weight at the minimum of cost, that was to say the practice was to build the 10-ton wagons above the sizes and strength laid down in the specification. As an illustration of this, the writer knew of a large number of 8-ton wagons which were built for a trader a few years ago; the actual carrying capacity of which was little more than 7 tons of coal, and the tare of this lot of wagons was 6 tons. Recently the firm with which the writer is connected built sixty 15-ton ore wagons for private owners; the tare of these was 6 tons 12 cwt., or gross load 21 tons 12 cwts., giving a load of nearly 10 tons per axle; the journals were 9 inches long by $4\frac{1}{2}$ inches diameter, the underframes were of steel 9 inches by 3 inches by $\frac{3}{8}$-inch channel section throughout, and the body was of red pine 3 inches thick. It was certainly very desirable to have a high-capacity wagon with a low tare, and if railway companies and wagon owners had to face automatic couplings, either side-brakes or automatic brakes, a great deal might be saved by the introduction of such a wagon, but to ensure its success the wagon should (for coal traffic) be self-discharging by hopper-bottoms, and as pointed out in the Paper, depôts or terminals would require to be arranged to meet those conditions.

Mr. Twinberrow, in replying to the communications, wrote that his object in designing the compensating buffer-frame was to ensure that the buffer-heads should always meet those of a given standard vehicle axially and in line on any curve, thus facilitating the application of automatic couplers. Correct working was ensured by the location of the pivot-pin on the centre line of the bogie-wagon at the point of intersection with the chord through the centres of the axles of the adjacent standard vehicle, Fig. 25, Plate 84. When equalised on this plan, long and short vehicles would work safely in contact on sharp curves, the trains might be tight coupled without fear of increasing the frictional resistance, and the arrangement would possess all the advantages and none of the faults of central couplers.

(Mr. Twinberrow.)

There was undoubtedly a field of usefulness for box-cars with side and bottom openings as described by Mr. Jepson (page 597), but the necessary hand-labour in unloading unfitted them for use in the shipping trade. The radial guide-links of his bogie were amply sufficient to communicate to the body retardations far in excess of the adhesive power at the treads of the wheels. He expected that the distinctive features of this bogie would commend themselves to a number of railway men who appeared to have some objection to the customary types. Recognising the existence of a lack of enthusiasm for bogie vehicles, he thought that a suitable design for four-wheeled wagons would secure a certain limited acceptance, he had therefore followed successful practice in adopting a cantilever truck. Though he did not suppose for a moment that these vehicles would run as well as bogie stock, he was convinced that their stability was sufficient for the purpose, and that they would be superior to ordinary wagons of equal capacity in the matters of tractive resistance and wear of flanges.

He did not agree with Mr. Jones that the bogie system gave no superiority in the ratio of load to tare compared with four-wheeled wagons of short wheelbase (page 598); when it was not so in ordinary practice he saw an indication that the designer had not risen to the opportunity, as the saving of weight in headstocks ends, couplers, brake rigging, etc., should provide more than sufficient material for securing the necessary additional vertical rigidity of the long body.

Comparisons based simply on the loads for which the axles and springs were designed were likely to be illusory, unless the floor area of platform-wagons and the cubical contents of box-cars were also given. He also feared that there was an error in Mr. Jones's estimate of the capacity gained by replacing the timber sides and ends by thin plates with internal stiffeners. By such means 5 per cent. would be gained in width and less than 3 per cent. in length; by adding a foot to the length the latter figure would be raised to 9 per cent., and 6 per cent. might be added to the depth. The ratio of the new capacity to the old was then $109 \times 105 \times 106 : 1{,}000{,}000$; or a gain of 21·3 per cent. Similarly the standard coal-wagon of the North Eastern Railway had a self-discharging hopper, the end slopes of which commenced a little below the curb; the additional capacity gained by continuing the slopes for a distance of 6 inches at each end would be very trivial. The standard steel wagon of the East Indian Railway had a wheelbase of 11 feet 6 inches, and measured 19 feet 3¾ inches by 9 feet inside the body, the net capacity of which was only 478 cubic feet, or say 11 tons of coal. He believed that these wagons would not run over the curves on the frontier lines of the North Western system, and he could not accept them as satisfactory models for this country.

The possibility of building wagons to fulfil the conditions necessary for supporting the investigation which Mr. Jones had made was however established beyond question, and he hoped that this careful and logical presentation of the case would be noted by those responsible for wagon renewals on British railways. Though the ordinary wagon had a life of twenty or twenty-five years, it required continuous expenditure to maintain it in working order. One of the leading companies had to repair its wooden wagons at an average interval of only ten months, and when the superior economy of an improved design was admitted, it would appear reasonable to scrap the older stock as it required heavy repairs, investing the equivalent of the cost to better advantage in new stock.

He was pleased to observe that Mr. Aspinall was increasing the hauling power of his engines; he himself had long been an advocate of this course,* but regretted that our railways had not commenced to work trains of even 1,000 tons gross, until 2,000 tons had become the standard practice elsewhere.

He noted that the hopper-wagon referred to by Mr. Jones had slopes inclined at 30° only, Fig. 30, Plate 86, as usual in American practice. It would not therefore be self-clearing when loaded with small or damp coal, and he preferred a steeper inclination. One of the leading objects he had in view was to avoid accidental opening of the doors in the event of any part failing; he did not approve of

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* See *The Mechanical Engineer*, 2 July, 1898; *Engineering*, Vol. 67, pp. 357, 738–9; Vol. 66, pp. 111, 242; Vol. 59, p. 124; Vol. 57, p. 175; etc.

(Mr. Twinberrow.)

using eight doors when two were sufficient, especially when the larger number depended for security on chains and ratchet wheels. If the wagon illustrated were of the same height and width as the author's, but with 36-inch wheels and steeper slopes, its capacity when 27 feet long inside was only 27 tons, when the coal was heaped 6 inches above the curb; and the length must be increased to 34 feet 4 inches in order that it might hold 36 tons, in which case the area of the doors would be very great, and the cost and weight proportionately increased.

He was of opinion that the buckling of iron side-doors referred to by Mr. Cree Maitland (page 605) was largely due to the omission of proper precautions to check or cushion the fall when thrown open. Sliding doors were of course free from such risk, and had already proved successful by several years of service in 10-ton wagons. The friction between the plates of laminated springs increased with age as corrosion progressed, and its effect in other situations was to damp out the synchronous oscillations to which helical springs were subject. The weight of his bogie with cast-steel frames, channel transoms, and castings for side bearings was 1,495 lbs. He had found the current British price of reliable steel castings to be too high for his purpose, and he had more recently designed a bogie with flanged-plate frames, having cast-steel axleguards riveted in place. The weight of similar parts of this example was 1,652 lbs., the wheels and axles, journal boxes, springs, brake work, etc., were not included. The advantage of dispensing with the bolster was apparent. He had not thought it desirable to confuse the issue by introducing financial estimates, proposals for general merchandise traffic, or comparisons with American practice; he had, however, prepared some diagrams showing some particulars of American railway working, Figs. 31–36, pages 614–5, which he feared would not be gratifying to those responsible for British practice.

The cost of the large steel-wagons at current prices for material was about £8 per ton of capacity, being somewhat higher for 30-ton cars and lower for the larger sizes. This figure included the cost of air-brake equipment, and the materials were such as to comply with the requirements of British railways. It was however not unusual to find clauses in English specifications for colonial and other work, which necessitated a very considerable addition to the cost. It was necessary to draw on American sources for information as to the cost of maintenance; he understood that the annual cost of painting and repairing the wagons of the Pressed Steel Car Co. hitherto varied from 40*s.* to 60*s.* each. Some interesting information was also available concerning their behaviour in collisions and other accidents; though it would not pay to fortify vehicles especially against such infrequent and accidental occurrences, it was apparent that these wagons possessed remarkable powers of resistance. Four wagons broke away from a train on the Pittsburg and Western Railway, and ran back for a distance of about 1,000 yards when they were brought up by ten cars standing at the foot of the incline. Car No. 4001 received the full force of the collision, and the necessary repairs were effected at a cost of £8. Car No. 4387 was returned to the makers with damaged sides, headstocks, and brackets; the repairs cost £7 14*s.* Car No. 4211, loaded with 45½ tons of stone, fell from a bank about 15 feet high on to another line of way; the damage was put right at a cost of £7 15*s.*

The yearly cost of wagon repairs on British railways appeared to average £5 4*s.* each; it would seem therefore that the maintenance of the high-capacity wagons might increase with age, and yet not exceed one-fourth of that of the small wagons per unit of capacity.

He was not willing to use larger wheels, as they involved greater weight, increased height, longer wheel-base, and larger journals in order that the peripheral speed of the surfaces should be sufficiently great to maintain an oil film when travelling at low speed. Large wheels were usually an indication of an extravagant design. Some twelve years ago he had designed a steel wagon upon four axles, the outer pair having radial boxes and the inner pair fixed, as in some of the coaches of the London and North Western Railway, but his experience of the running of this class of wheel-base was decidedly unsatisfactory. The Great Northern Railway had built some coaches on four axles, the rigid wheelbase being 31 feet 6 inches and the inner axles having lateral play; he thought the arrangement was only suitable for moderate speeds and straight roads. Equalised

(Mr. Twinberrow.)

Railway Working in U.S.A. 1892–1899. (For all lines.)

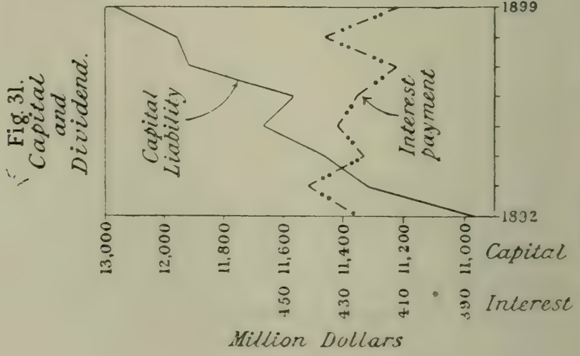


Fig. 31. *Capital and Dividend.*

Difference between 1892 and 1899 } Capital + 10·9% } Interest − 3·3%

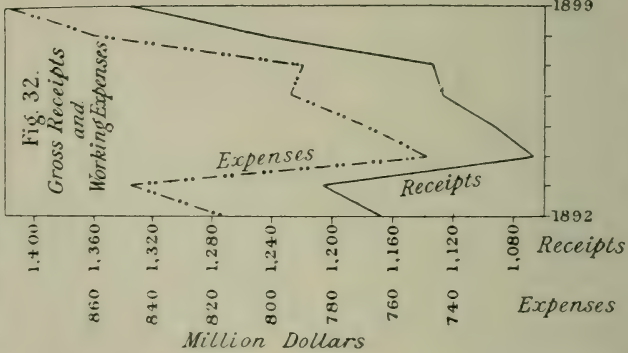


Fig. 32. *Gross Receipts and Working Expenses.*

Receipts + 14·3%
Expenses + 8·7%

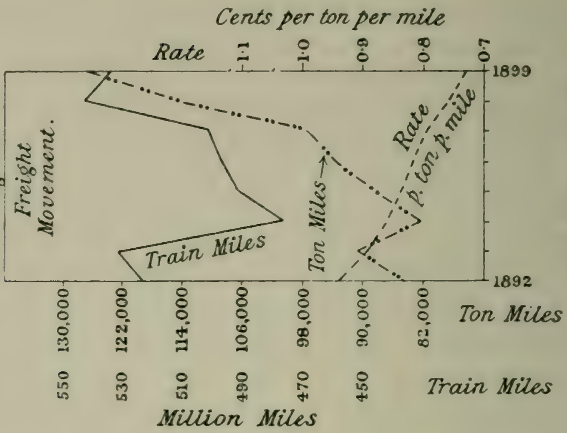
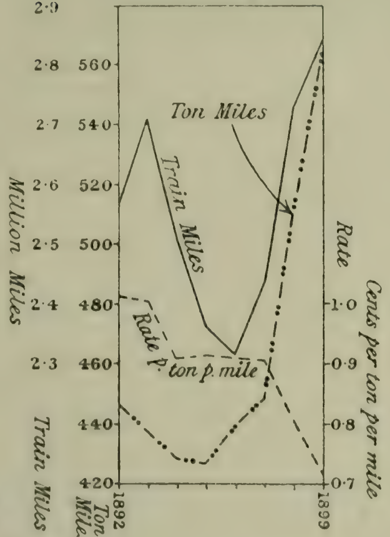


Fig. 33. *Freight Movement.*

Train' Miles + 2·0%
Ton " + 50·5%
Rate − 22·8%

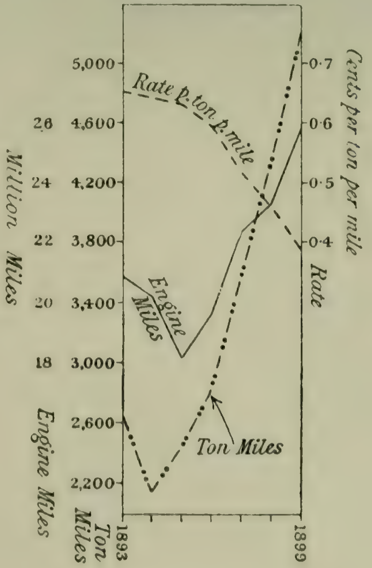
Railway Working in U.S.A. 1892 *and* 1893–1899. *Freight Movement.*

Fig. 34. *Boston and Albany R.R.*



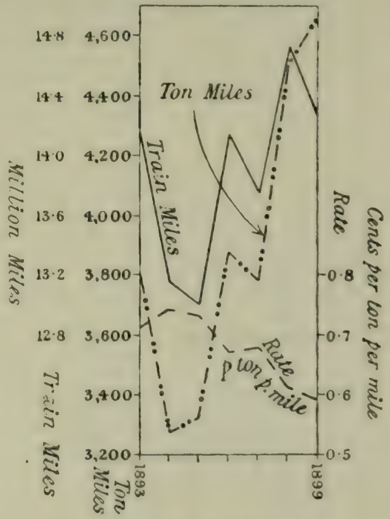
Difference between 1892 and 1893 –1899 } Train Miles + 11·1%
Ton " + 26·4%
Rate – 28·4%

Fig. 35. *Baltimore and Ohio R.R.*



Engine Miles + 23·2%
Ton " + 92·9%
Rate – 40·0%

Fig. 36 *New York Central and Hudson River R.R*



Train Miles + 0·3%
Ton " + 21·6%
Rate – 16·9%

(Mr. Twinberrow.)

loading and independent angular motion in horizontal and vertical planes were necessary for economical maintenance and easy running.

Mr. R. Lauder Maclaren had devoted much attention to the design of axles fitted with wheels capable of rotating independently. He thought that the extra weight and cost would render them useful only for mountain railways having a large proportion of curves of sharp radius.

Mr. C. S. Meik's remarks showed that dock engineers were alive to the importance of this subject, and he did not think that private-wagon owners would be slow in taking up larger wagons, when the railways modified their attitude ; hitherto they had some grounds for the belief that the railways would refuse to deliver or to work high-capacity wagons. If assured of the support of the railway companies, he would have great pleasure in complying with Mr. Aspinall's suggestion (page 588), and would do his best to persuade the dock and colliery companies to effect the necessary alterations.

The Institution of Mechanical Engineers.

PROCEEDINGS.

December 1900.

The December Meeting was held at the Institution on Friday, 14th December 1900, at Eight o'clock p.m.; Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S., President, in the chair.

The Minutes of the previous Meeting were read, approved, and signed by the President.

The President made the following announcements:—

That, in accordance with the Rules of the Institution, the President, two Vice-Presidents, and five Members of Council, would retire at the ensuing Annual General Meeting; and the list of those retiring was as follows:—

PRESIDENT.

Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S.,	London.

VICE-PRESIDENTS.

Arthur Keen,	Birmingham.
T. Hurry Riches,	Cardiff.

MEMBERS OF COUNCIL.

Sir William Arrol, M.P., LL.D.,	Glasgow.
William Dean,	Swindon.
Bryan Donkin,	London.
H. Graham Harris,	London.
A. Tannett-Walker,	Leeds.

That of these the following had offered themselves for re-election, and were now nominated by the Council:—

VICE-PRESIDENTS.

Arthur Keen,	Birmingham.
T. Hurry Riches,	Cardiff.

MEMBERS OF COUNCIL.

William Dean,	Swindon.
Bryan Donkin,	London.
H. Graham Harris,	London.
A. Tannett-Walker,	Leeds.

That the following additional Nominations were made by the Council for the election at the Annual General Meeting:—

PRESIDENT.

William H. Maw,	London.

MEMBERS OF COUNCIL.

Election as Member.		
1860.	Henry Lea,	Birmingham.
1871.	Sir John Wolfe Barry, K.C.B., LL.D., F.R.S.,	London.
1884.	Sir W. Thomas Lewis, Bart.,	Aberdare.
1898.	James Swinburne,	London.

That all of the above had consented to the Nomination.

The President reminded the Meeting that, according to the Rules of the Institution, any Member or Associate Member was now entitled to add to the list of candidates.

The following nomination was then made by Professor W. W. F. Pullen, M.I.Mech.E., and seconded by Mr. Hugh Campbell, M.I.Mech.E.:—

MEMBER OF COUNCIL.

1885.	William Henry Fowler,	Manchester.

The PRESIDENT announced that the foregoing names, subject to the consent of the one added,* would accordingly constitute the nomination list for the election of Officers at the Annual General Meeting.

A Paper was read and partly discussed entitled:—

"Power-Gas and large Gas-Engines for Central Stations;" by Mr. HERBERT A. HUMPHREY, M. I. Mech. E., of Northwich.

This Paper, with full subsequent discussion, will be found in Part I of the Proceedings 1901.

The Meeting terminated at Half-past Nine o'clock. The attendance was 184 Members and 175 Visitors.

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* Mr. Fowler subsequently signified his consent to the nomination as a candidate for Member of Council.

MEMOIRS.

Professor George Frederick Armstrong was born in Doncaster on 15th May 1842. His general education was received at King's College, London, and Jesus College, Cambridge; subsequently he returned to King's College, and attended the engineering classes. His professional career was commenced in 1855 in the locomotive and rolling-stock works of the Great Northern Railway, and as pupil from 1863 to 1865 in the office of Mr. R. Johnson, engineer-in-chief of the company. Afterwards he was a member of the engineering staff from 1865 to 1869, and was employed in the locomotive works and in the maintenance of the line. He was next engaged in private practice in London, and in 1869 became the engineer for the promoters of the Isle of Man Railways. In 1871 his work as a public teacher was inaugurated by his election as first professor of engineering in the Applied Science School of McGill University, Montreal, in which position he remained until 1876, when he returned to England to take up the duties of the engineering chair at the Yorkshire College of Science, Leeds. In 1885 he was appointed by the Crown to succeed Professor Fleeming Jenkin, as Regius Professor of Engineering in the University of Edinburgh. In that capacity he delivered, as an inaugural address, a lecture in which technical education was very prominently dealt with. During his term of office he obtained for his pupils an engineering laboratory. He gave special attention to sanitary work, and to questions regarding water supply; and in this connection he was appointed engineering adviser, under the Public Health Act, to the Local Government Board for Scotland. He was closely associated with the work of promoting and organising the two Edinburgh International Exhibitions in 1885 and 1890, in the latter of which he was convener of the Engineering and Machinery Committee, and vice-chairman of the Executive Council. He was president of the

Sanitary Engineering Section of the British Institute of Public Health in 1893; and in connection with the last meeting in Edinburgh of the British Association he acted as secretary, and was chairman of the Executive Committee of the Edinburgh Meeting of this Institution in 1887. In the following year he acted as local secretary at a similar meeting of the Iron and Steel Institute. During 1879 he undertook an elaborate series of observations and experiments with a view to determining the diurnal variations in the amount of carbon dioxide in the air, the results of which were communicated to the Royal Society of London, and have since been accepted as a standard of reference. In 1889 he was made a Fellow of King's College, London. He was an examiner for science degrees in the departments of engineering, public health, and agriculture in the University of Edinburgh, and was a member of several institutions and societies, including the Royal Society of Edinburgh. After an illness of several months from an affection of the heart, his death took place at his residence at Grasmere, Westmoreland, on 16th November 1900, in his fifty-ninth year. He became a Member of this Institution in 1882.

Charles Henry Bingham was born in Sheffield on 28th May 1848. He was educated at Tinsley Vicarage, afterwards at Storthes Hall, near Huddersfield, and subsequently at Neuwied on the Rhine. After serving a short time at the locomotive works of the Great Northern Railway at Doncaster, he entered the electro-plate and cutlery works of Messrs. Walker and Hall, at Sheffield, when the business was being carried on by his elder brother, Colonel J. E. Bingham, and his uncle, the late Mr. H. Hall. On the retirement of the latter he became a partner, devoting himself more particularly to the manufacturing part of the business, to the extension of the premises, and to the inventing and perfecting of the machinery. In 1882 he joined the Cutler's Company, and was Master Cutler in 1894–1895. Having been in indifferent health for some months, his death occurred rather suddenly at his residence in Sheffield on 2nd October 1900, at the age of fifty-two. He became a Member of this Institution in 1890.

John Grant Birch was born on 27th April 1847 in the Island of Antigua, West Indies, where his father, Colonel J. F. Birch, was then stationed as Garrison Staff Officer. Coming to this country a few years later, he entered in 1867 the service of Messrs. Laird Brothers of Birkenhead, and remained with them until 1872. He then started in business on his own account as engineer and iron merchant in Liverpool. During his early business career he held numerous agencies, and after a while turned his attention to export business and the representation of foreign engineers, which gave rise to repeated journeys round the world. The main business of his firm was moved to London at the beginning of 1890, and its principal direction remained in his hands until his death. His work included a long series of important contracts specially connected with railway and marine engineering. In 1896 he obtained, in conjunction with Mr. John S. Horner, a concession from the Egyptian Government for the construction of light railways, resulting in the formation of the present Egyptian Delta Light Railway Co. When the method of advance into the Soudan was under consideration, a detailed scheme for the construction of the railway across the desert was submitted to the Egyptian Government by him, and though the funds then available were insufficient for carrying it out at the time, the plan actually adopted in the following year was substantially that which he had proposed. In September 1899 he left England for China for the purpose of surveying the country of the Upper Yangtsze district with a view to railway enterprise. This having been accomplished, he travelled to Lanchow, intending to make his way to Peking, viâ the Yellow River and the Great Wall. In descending the Yellow River he lost his life, through the wrecking of the raft on which he was travelling, on 24th June 1900, at the age of fifty-three. He became an Associate of this Institution in 1890.

William Borrows was born at Sutton St. Helens, Lancashire, on 6th August 1850. After having been educated at Ampleforth College, Yorkshire, he entered the workshops of his father, Mr. Edward Borrows, at St. Helens Junction, and served his time as a turner. On the completion of his apprenticeship he passed through the various departments in the works, and in this way acquired a full practical experience which enabled him to take the management of the business on the death of his father in 1881. He devised an improved method of grinding and polishing plate glass, and invented a grip plate for attaching pedestal hangers and brackets to rolled joists, beams, or cast girders, without drilling holes through the flanges. Having been in failing health for some months, his death took place at his residence at Sutton St. Helens, on 24th September 1900, at the age of fifty. He became a Member of this Institution in 1888.

Robert William Eddison was born in Leeds on 28th September 1835, and was the eldest son of Mr. Edwin Eddison, the first Town Clerk of Leeds. He was educated at Hitchin and Queenswood College, Stockbridge, Hampshire, and was afterwards articled to his father with the intention of becoming a solicitor. Sedentary office work, however, proved hurtful to his health, and in 1856 he spent a year travelling through the United States and Canada. On his return to Leeds in 1857, the great interest he took in agriculture brought him into close touch with his friend Mr. John Fowler, the inventor of the steam plough and founder of the firm of John Fowler and Co., which was then engaged in the development of this invention. He became associated with Mr. Fowler during the building of the Steam Plough Works, and again visited the United States in the interests of the business in 1860 and 1861. He saw a good deal of the Civil War, and was present at the battle of Bull Run. On the formation of the firm of John Fowler and Co., he was taken into partnership, and played a prominent part chiefly in connection with the commercial department, representing the firm at the principal shows of the Royal Agricultural Society. He was on the executive of the Yorkshire Agricultural Society, and was chairman of the Agricultural Engineers' Association in 1898–1899. He was also one of the founders of the National Traction Engine Owners and Users' Association, chairman of the Iron Trade Employers' Insurance Association, a member of the committee of the

Iron Trade Employers' Association and of the Engineering Employers' Federation, and other societies. His connection with agriculture was extended to his private life, as he farmed his own estate at Adel. He took a leading part in the passing of the various Acts of Parliament since 1861 for regulating the use of traction engines on highways. His great attention to business prevented his taking any prominent part in public affairs, and led him to decline magisterial honours, but when the Adel Parish Council was established, and he was elected its first chairman, he consented to serve. His death took place at his residence at Adel, near Leeds, from acute pneumonia, after four days' illness, on 21st May 1900, in his sixty-fifth year. He became a Member of this Institution in 1868.

Henry Garbutt was born in Birmingham on 24th March 1871. After having been educated at Aston Higher Grade School he served his time from 1886–1889 in the shops of Messrs. Ticehurst, Tolley and Co. On its completion, he was employed in the engineering shops of Messrs. Kynoch, Birmingham. In 1892 he was transferred to the drawing office of the same firm, subsequently being appointed chief draughtsman. He was afterwards appointed manager of the cycle department of Messrs. Kynoch, and later on was promoted to a responsible position in the inspection department of the Company's Ammunition Factory. He was well known for the lively interest he took in technical education, upon which subject he was an authority and able lecturer. During the latter five years of his life he lectured to scholars at each of the science classes in Birmingham, Aston, and Erdington Technical Schools; and his efforts, combined with his explicit mode of instruction, were rewarded by the satisfaction of having a large number of his students pass the examinations. His death took place in Birmingham from typhoid fever, on 6th August 1900, at the age of twenty-nine. He became an Associate Member of this Institution in 1899.

Göran Fredrick Göransson was born in Gefle, Sweden, on 20th January 1819. He started in business as a merchant, but later on became interested in steel making, having bought one-fifth of Mr.

(afterwards Sir) Henry Bessemer's Swedish patents, and succeeded in making good Bessemer steel at his ironworks at Edsken and Högbo as early as 1858. In 1862 he founded the Sandvik Iron Works for the production of this steel, and they are now one of the largest in the country, employing about 2,000 men. He was chairman of the company until his death, which took place at Sandvik on 12th May 1900, at the age of eighty-one. In addition to his various honorary distinctions he was a Commander with the Great Cross of the Royal Order of Vasa, and a Knight of the Royal Order of North Star; and the University of Upsala had conferred upon him a few days before his decease the degree of Doctor of Philosophy. He became a Member of this Institution in 1865.

John Robert Jefferies was born at Great Barford, Bedfordshire, on 22nd December 1840. He went to Ipswich in 1856 to become a premium apprentice to Messrs. Ransomes and Sims at the Orwell Works, and on the completion of his apprenticeship he was sent to Russia by the firm to erect and start machinery supplied by them. On his return to England he continued in the employment of the firm, and was taken into partnership in 1871, becoming one of the managing directors when the undertaking was converted into a private company in 1884. He originally devoted his attention almost exclusively to the manufacturing department of the works, but as other partners passed away he also undertook the control of the firm's foreign and colonial trade. This work necessitated frequent continental journeys, and he also paid several visits to the United States, in the resources and industries of which country he always took a great interest. He introduced many improvements in the various classes of machinery and implements made at the Orwell Works, amongst which may be specially mentioned the well-known lifting apparatus for double-furrow and multiple ploughs. Hitherto it had been impossible to bring these ploughs into general use, owing to the difficulty of raising them out of the land and of turning them at the ends of the furrows; but the ingenious arrangement of wheels and axles invented by him entirely obviated this difficulty. At the present time multiple ploughs are extensively used all over the world, and the arrangement invented by him has been adopted by all the principal plough-makers in England and abroad. In 1882 he was elected one of six representatives of the burgesses of Ipswich on the Dock Commission, and was chosen a member of the Committee of Management in September of the same year, from which time until his death he took the greatest interest in the improvement of the port. In the Ipswich Chamber of Commerce and Shipping, formed in 1884, he succeeded the first chairman, and in the present year (1900) was again elected to that position. He was a great mover in the establishment of the Ipswich Girls' High School, in which he always took a keen interest. He was also a Justice of the Peace for the Borough, and was Chairman of the Agricultural Engineers' Association for 1900. His death took place at Ipswich, on 12th September 1900, in his sixtieth year. He became a Member of this Institution in 1880; and was also a Member of the Iron and Steel Institute.

Robert Baird Kennedy was born at Ayr on 17th November 1853, and was educated at Ayr Newton Academy. He served his apprenticeship from 1868 to 1873 at Messrs. J. and T. Young's marine-engine works, Vulcan Foundry, Ayr; and on its completion remained with the firm for a year as junior draughtsman. From 1874 to 1876 he was assistant manager to his father at the plumbing trade in Glasgow. He next went to sea as engineer until 1886, when he was appointed assistant superintendent and surveyor to Messrs. Esplen and Son, consulting engineers and naval architects, of Liverpool. In 1891 he became outside manager to Messrs. J. and E. Hall, refrigerating engineers, of Dartford, and in 1892 he commenced business on his own account at Grimsby as consulting engineer, surveyor, and refrigerating expert. In 1898 he removed to Middlesbrough, where he started a steam laundry. His death took place at Middlesbrough on 21st June 1900, in his forty-seventh year. He became an Associate Member of this Institution in 1895.

James Macnab was born at Newton, near Hyde, on 6th February 1872. After receiving his education at private schools and at the

Manchester Grammar School, he served his apprenticeship from 1888 to 1893 in the works of Messrs. Pollock and Macnab, engineers, Hyde. From 1893 to 1895 he superintended the erection of work in the shop, after which he went to Brazil to superintend the erection of sugar-mill machinery on various estates. In 1898 he became managing director of the firm of Messrs. Pollock and Macnab. Business affairs had frequently taken him to South America, and on his return from Bahia in May he was seized by a virulent attack of typhoid fever which terminated fatally at Hyde on 17th July 1900, at the age of twenty-eight. He became an Associate Member of this Institution in 1898.

James Moir was born in Aberdeen on 18th December 1855. He served an apprenticeship of five years as an engineer with Messrs. Hall, Russell and Co., of Aberdeen, and on its termination was engaged as a marine engineer in the Hall Line of steamers, ultimately becoming chief engineer. In 1883 he was appointed engineer to the Coorla Spinning and Weaving Co., Bombay, and shortly afterwards became engineer surveyor to Lloyd's Register for the port of Bombay. In addition to these appointments he became in 1888 superintending engineer to the Bombay Steam Navigation Co., and remained with them until 1896, when, in conjunction with his partner (also Mr. James Moir), he purchased Boyd's Ice Factory, and took an active share in its management. He was also superintending engineer to the Bombay-Persian Steam Navigation Co. for about a year prior to his death, which took place in Bombay, from typhoid fever, on 25th March 1900, at the age of forty-four. He became a Member of this Institution in 1885.

Louis Irving Seymour was born at Whitney's Point, State of New York, in 1860, and was educated at the Academy, in the same town. His mechanical engineering training was started in 1881 at the Lackawanna Iron and Steel Co.'s works at Scranton, Pennsylvania, where he worked as a fitter, Bessemer steel-blower, and foreman in charge of rolling-mill machinery. In 1884 he was employed at the works of the Dickson Manufacturing Co. in the same town, erecting machinery and boilers. Having shown considerable ability he was sent by the latter firm in 1886 as chief engineer of the El Callao Gold Mine in Venezuela until 1888, when he was appointed chief engineer of the Plymouth Cordage Co.'s works at Plymouth, Massachusetts. In 1890, at the age of thirty, he became chief mechanical engineer to the De Beers Consolidated Mines at Kimberley, and held that position until 1893. During that period he effected great economies in the existing machinery and plant. The winding engines that he designed and erected there in 1892 hold the record for fast hoisting compared with any engine of their size, for from a depth of 1,260 feet 3,700 tons have been raised in twelve hours, and 6,500 tons in twenty-four hours. During the last nine months of 1893 he held the position of acting general manager. At the Kimberley Exhibition in 1892 he took a most active part, and was chairman of the Machinery Committee. In 1893 he returned to London, and became manager of the Erith works of Messrs. Fraser and Chalmers, and subsequently managing director, which position he held until 1896. He was also consulting engineer to the De Beers Consolidated Mines as well as to the Rand Mines during this period. In 1896 he had the choice of two appointments offered to him, namely, engineer to the Central London Railway and chief engineer to the Rand Mines and other companies with which Messrs. H. Eckstein and Co. were connected. He accepted the latter position, and remained in Johannesburg until after the declaration of war, leaving on 14th October 1899. In Cape Town he became interested and largely instrumental in the formation of the Engineer Corps known as the Cape Railway Pioneer Regiment, of which he received the commission of Major. This regiment, numbering nearly one thousand, was recruited mainly from the engineers and mechanics of all kinds from the Rand. Though they were organised purely as an engineering corps, they were armed for self-protection, and the casualties that have occurred proved the serious fighting the corps has undergone. His death occurred in a skirmish with the Boers at the Zand River, Orange River Colony, on 14th June 1900, at the age of forty. He became a Member of this Institution in 1894, and was connected with other kindred societies, being President of the South African Association of Engineers.

James Strachan was born at Newbyth, Haddingtonshire, on 29th February 1860. After receiving his education at Stenton School, Prestonkirk, and Daniel Stewart's College, Edinburgh, he was apprenticed in 1873 to Messrs. A. and W. Smith and Co., of the Eglinton Engine Works, Glasgow, and was employed for seven years in the workshops and drawing office. On the dissolution of the firm he was engaged by Messrs. William Smith and Sons as draughtsman at the Partick Engine Works, Glasgow, with whom he remained one year. In 1881 he was employed by Messrs. Mirrlees, Watson and Co., of Glasgow, in the design of pumping engines and of appliances used in sugar factories; and in 1882 was appointed by Messrs. Manlove, Alliott, Fryer and Co., of Nottingham, manager of their drawing office. In 1886 he was sent by this firm to the West Indies to superintend the erection of sugar and other machinery; and in 1890 was appointed manager of an engineering works at Pernambuco, Brazil, where he remained about a year. In 1894 he commenced business on his own account in London as consulting engineer, making a specialty of laundry and dyeing machinery. He was also engaged on the drainage of the City of Mexico. For many years he had been in ill-health, and his death took place in London from diabetes on 16th May 1900, at the age of forty. He became a Member of this Institution in 1888.

James Donnithorne Thomas was born at Newton Abbott, Devonshire, on 31st January 1843. He commenced his engineering training with Messrs. Appleby Brothers, London, in 1867, and was employed by Mr. Dyce Kaye on the Aberdeen Harbour Works in 1869. In March 1870 he was engaged by Mr. John Darlington, Mining Engineer, and in conjunction with him designed and erected machinery at the Ballycorkish Mines, Isle of Man, in 1871–1872, also in the Marbella Iron Ore Co.'s mines in Spain. In 1874–1875 he went to Norway to the Varaldso Mines, and again went to Spain in 1877 to the Rio Tinto Mines. Of late years he was chiefly engaged in the manufacture of explosives. His death took place at his residence in Stoke Newington, London, on 10th October 1900, in his fifty-eighth year. He became a Member of this Institution in 1889.

Thomas Thomas was born at Dowlais on 17th August 1833. He served his apprenticeship at the Rhymney Iron Works, and went through the drawing office. In 1854 he was engaged as engineer to the Treforest Iron Works, and in 1856 was appointed chief engineer to the Blaenavon Coal and Iron Works, and under his supervision new blast-engines and furnaces, new rolling mills and tyre mill were erected. He left for Cardiff at the latter end of 1863. In 1864 he became engineer to the Pontnewynydd Iron Works, and in 1866 general manager to the Llynvi Iron Works. He remained there until 1870, when he returned to Cardiff as consulting engineer, and was in private practice to the time of his death, which took place suddenly from paralysis at his residence on 12th April 1900, in his sixty-seventh year. He became a Member of this Institution in 1864.

John Wildridge was born at Airdree, Scotland, in 1849, and served seven years' apprenticeship as draughtsman and engineer with Messrs. Henderson, Coulborn and Co., of Renfrew. In 1874 he entered the service of the Eastern and Australian Steam Ship Co., and went to Singapore. For a short time he was confidential engineer in the King of Siam's dockyard at Bangkok, and subsequently was appointed superintending engineer of the company. In 1888 he commenced private practice as consulting engineer and naval architect in Sydney, acting for many years as consulting engineer to the Eastern and Australian Steam Ship Co., the Linde British Refrigeration Co., and other firms. In 1892 he entered into partnership with Mr. Russell Sinclair, under the title of J. Wildridge and Sinclair. He was a member of the Marine Board, and also of the Government Board of Experts. His death took place at his residence in North Sydney, after a lingering illness, on 21st July 1900, at the age of fifty-one. He became a Member of this Institution in 1886.

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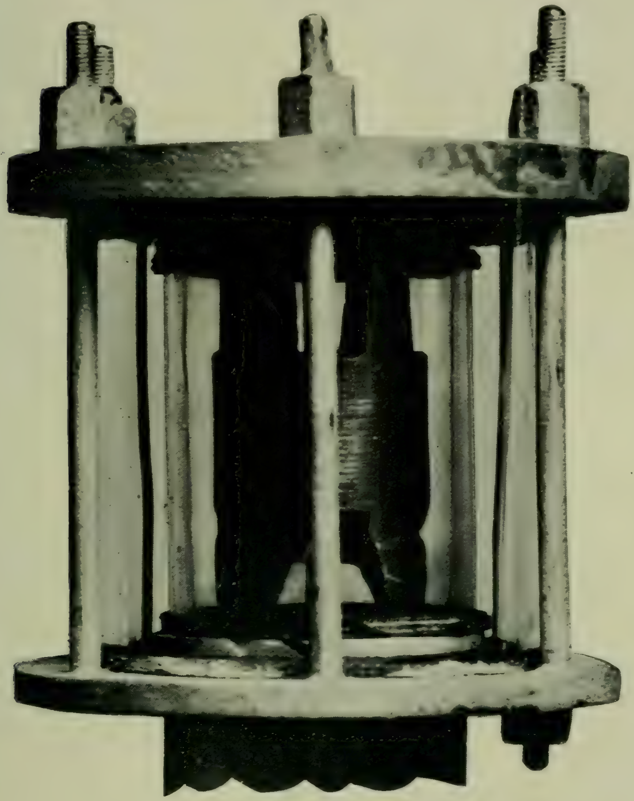
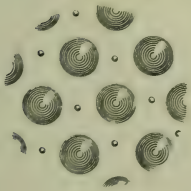
IMPROVED GLASS REVEALER.

Type 2, Non-Jacketed,
for studying Condensation in Steam-Engine Cylinders,
and rendering the effects visible. $\frac{3}{4}$ *Full size.*

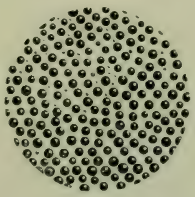


Appearance of Hemispherical Condensation Drops
in Non-Jacketed Revealer, Type 2, Plates 72 and 73.

From High-Pressure Cyl.,
magnified 25 diams.
Approximate diam.
$=\frac{1}{4}$ to $\frac{1}{5}$ $^{m}/_{m}$.

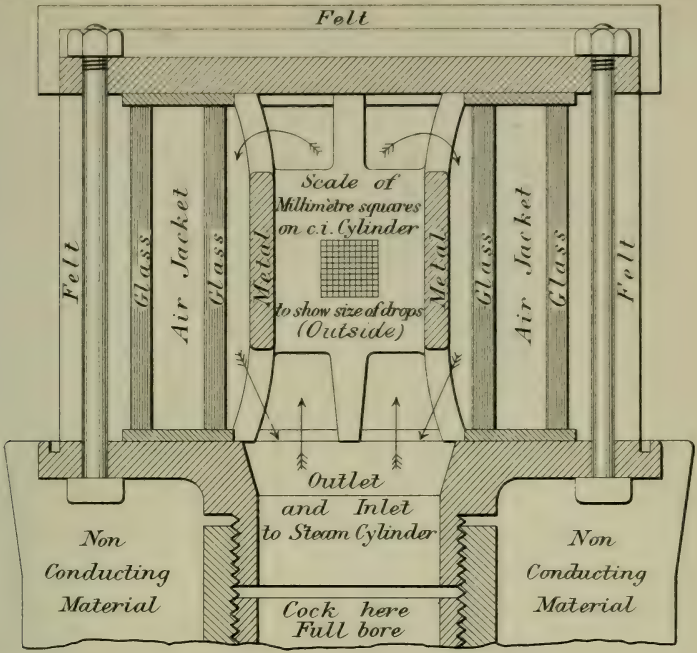


From Low-Pressure Cyl.,
magnified 25 diams.
Approximate diam.
$=\frac{1}{20}$ to $\frac{1}{25}$ $^{m}/_{m}$.

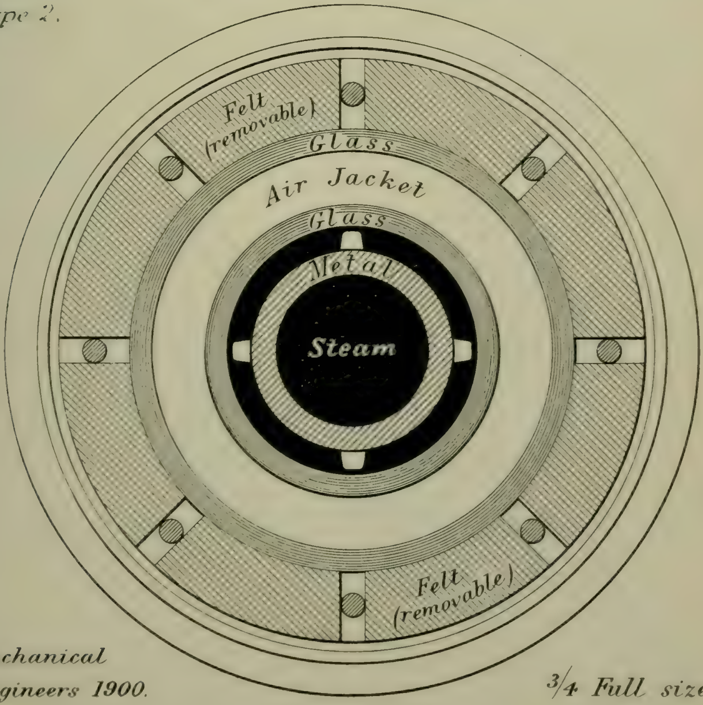


IMPROVED GLASS REVEALER. *Plate 73.*

Fixed on Steam-Engine Cylinder for showing Effects of Condensation, Re-evaporation, etc.



Type 2.



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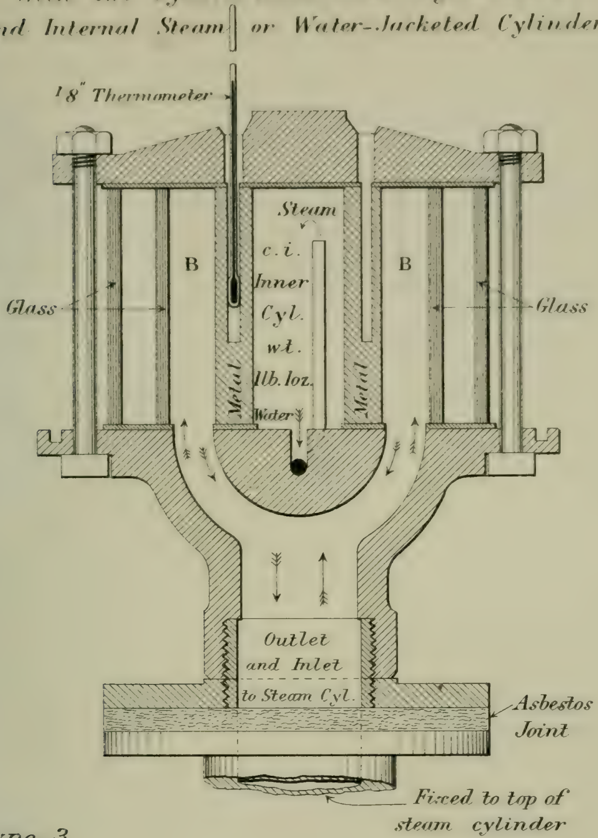
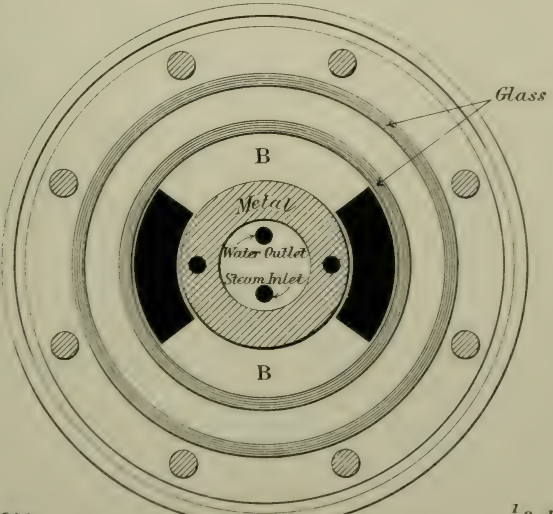
3/4 Full size

IMPROVED GLASS REVEALER. *Plate 74.*

With two Cylindrical Glass Cylinders
and Internal Steam or Water-Jacketed Cylinder.



Type 3.

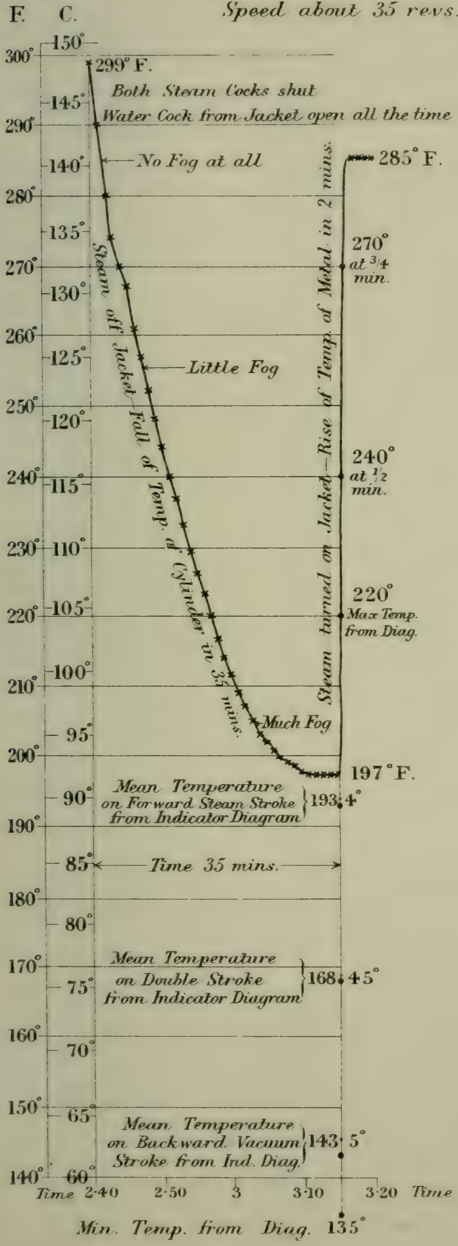


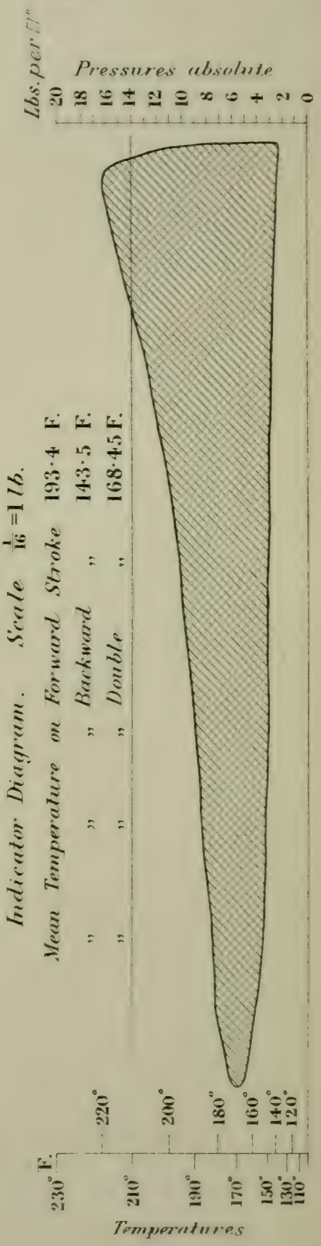
Mechanical Engineers 1900.

1/2 Full size

IMPROVED GLASS REVEALER. *Plate 75.*

Curve showing Fall of Temperature of Cyl. shown on Plate 74, exposed to Exh. Stroke &c. and so made as to be jacketed or not at pleasure, fixed on Low-Press. Cyl. of Factory Engine. Speed about 35 revs. per min.





Types of Wagons of High Capacity.

Fig. 9. *Coal Wagon to carry 17 tons (Tare 8 tons).*

17-ton wagons, 1000 tons gross, 680 paying = train 840 ft. long.
Standard 10-ton ,, 1000 ,, 620 ,, = ,, 1178 ,,

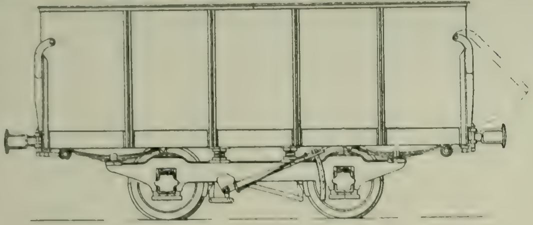


Fig. 10. *Flat Car to carry 17 tons,*

will carry 30% more paying load than ordinary 8-ton wagons with 7·4-tons tare.

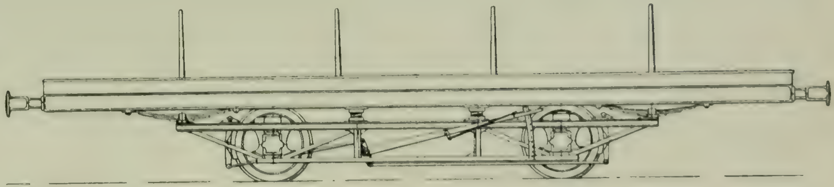
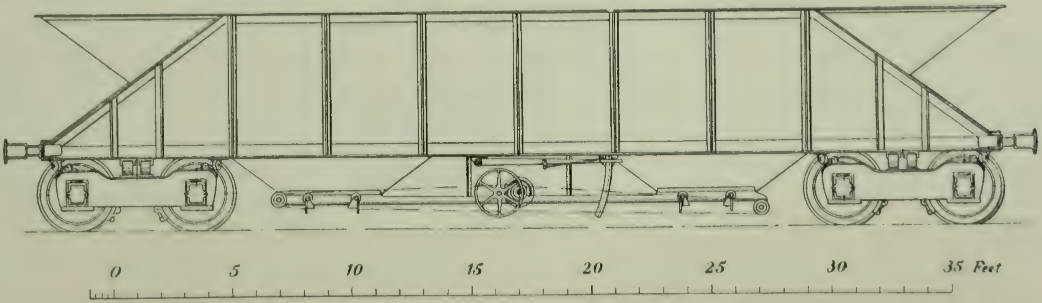


Fig. 11. *Hopper Coal Wagon to carry 36 tons (Tare 14 tons).*

A train of these wagons will carry 15% more paying load than a train of standard wagons of equal gross weight, the first cost will be 25% less per ton of capacity, and cost of repairs about 50% less.



Wagons on Short Wheel-bases to carry 17 tons.

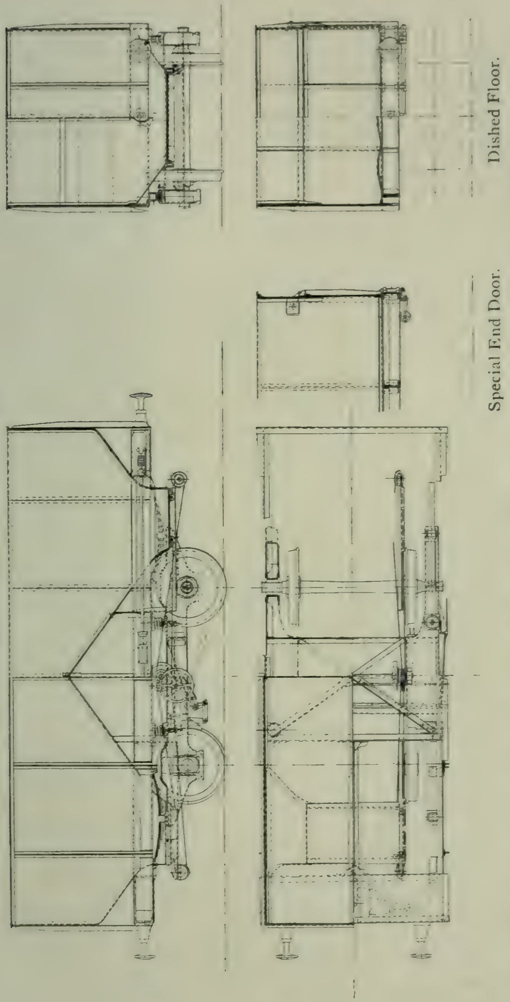


Fig. 12. *Hopper Wagon.*

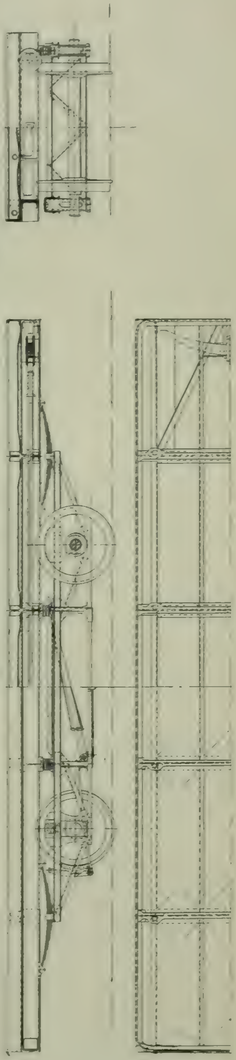


Fig. 13. *Wagon with 4 fixed Transom Bolsters, for rails, girders, timber, etc.*

CAPACITY OF RAILWAY WAGONS.

Bogie Wagons to carry 36 tons.

Fig. 14.

Hopper Coal Wagon.

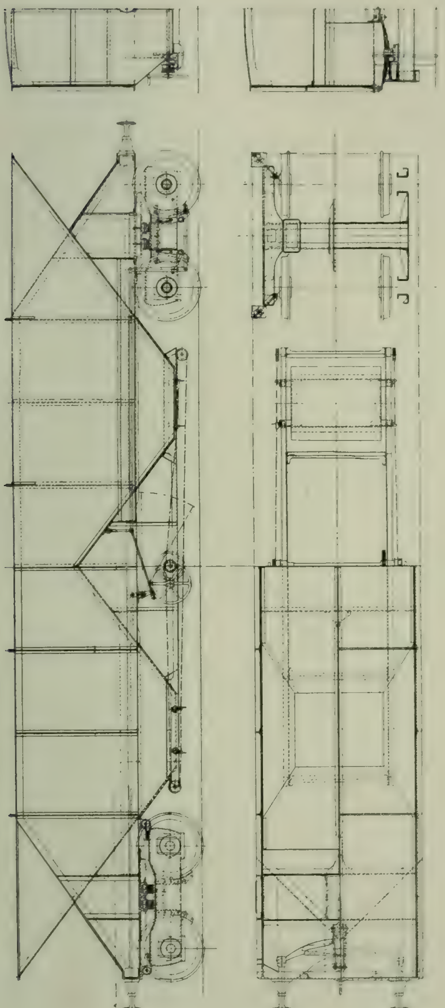
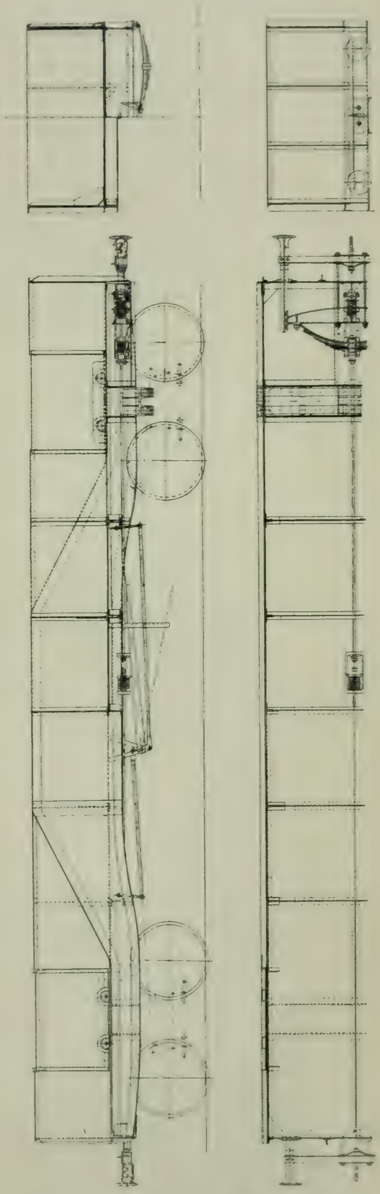


Fig. 15.

Wagon, for bricks, grain, etc.



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Scale for Fig. 14. 0 5 10 15 20 25 Feet

Scale for Fig. 15. 0 5 10 15 20 25 Feet

Fig. 16.

Bogie for Wagon weighing 50 tons gross.

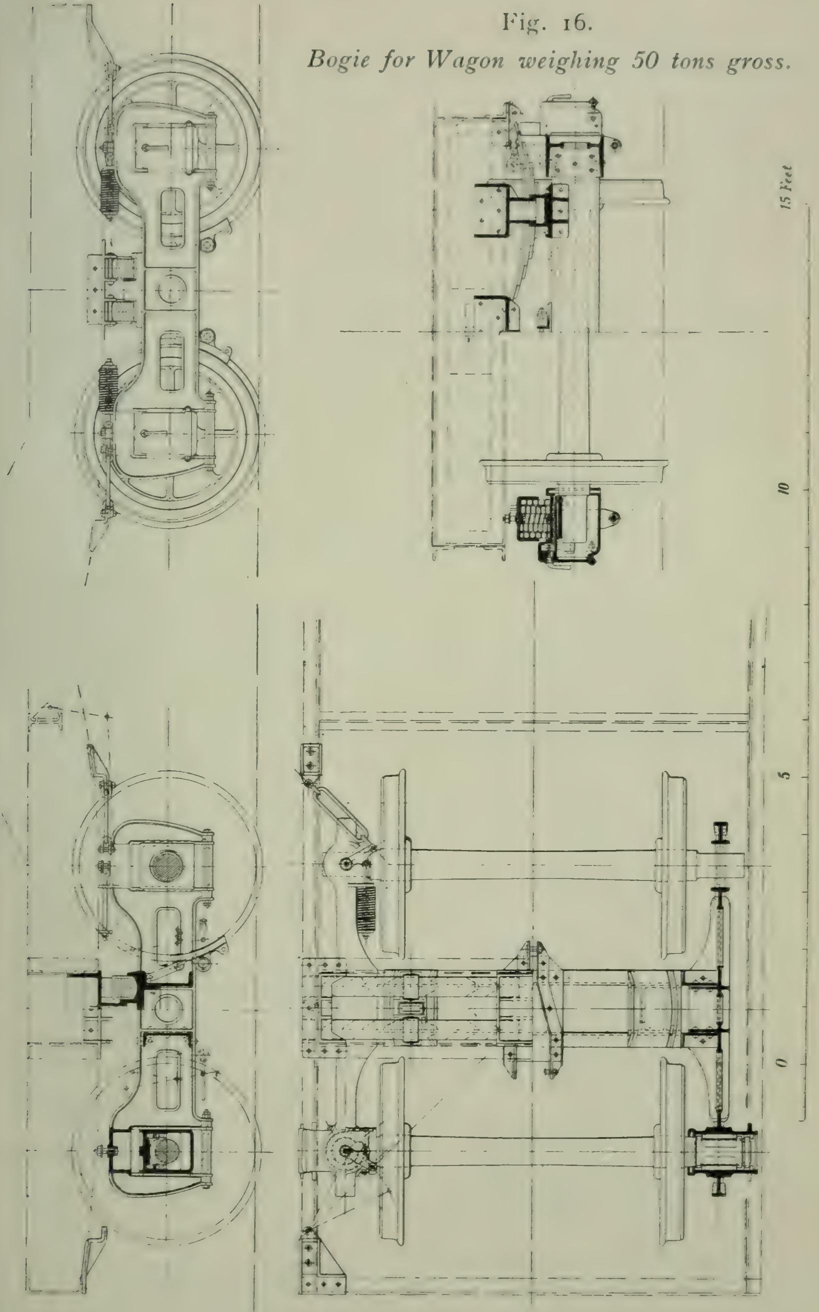


Fig. 17. *Scotch Coaling Crane.*

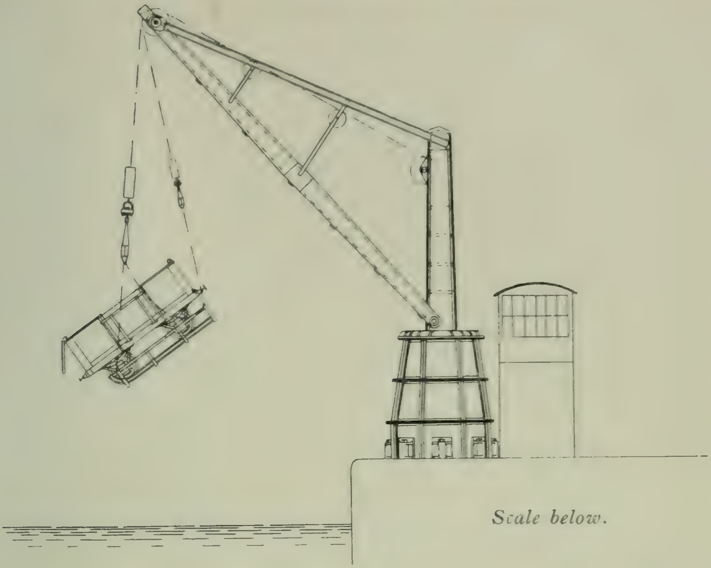


Fig. 18. *Welsh Coaling Tip.*

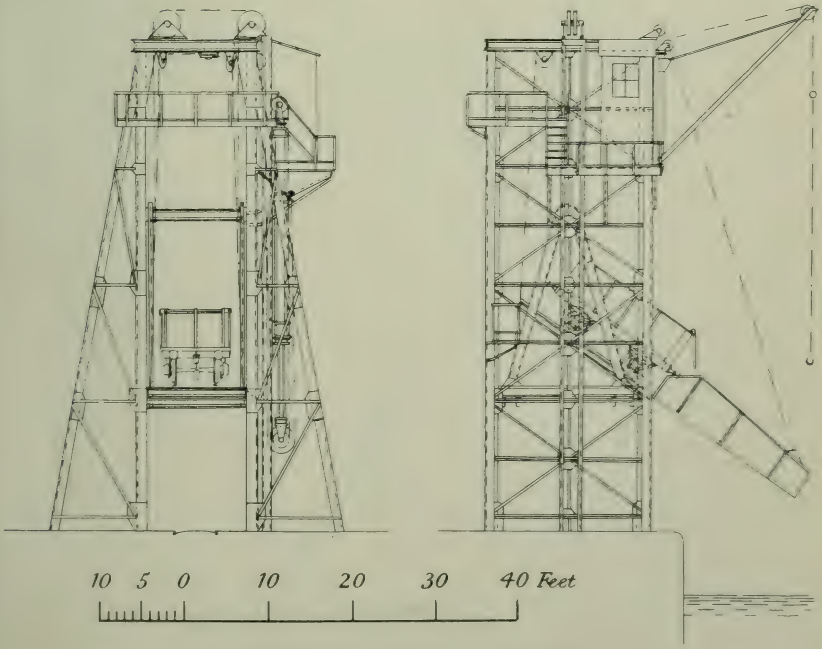
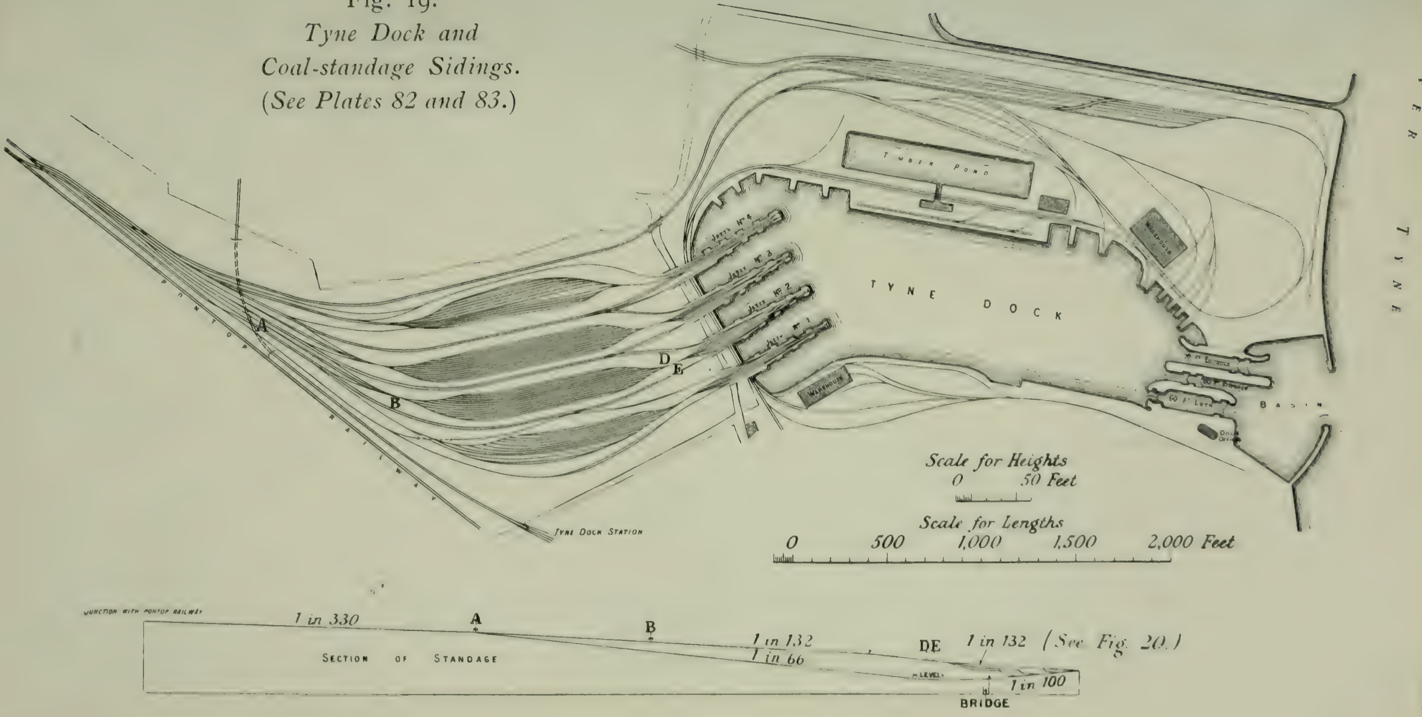


Fig. 19.
Tyne Dock and
Coal-standage Sidings.
(See Plates 82 and 83.)



CAPACITY OF RAILWAY WAGONS.

Fig. 20. *Coal-shipping Jetty. Tyne Dock.*

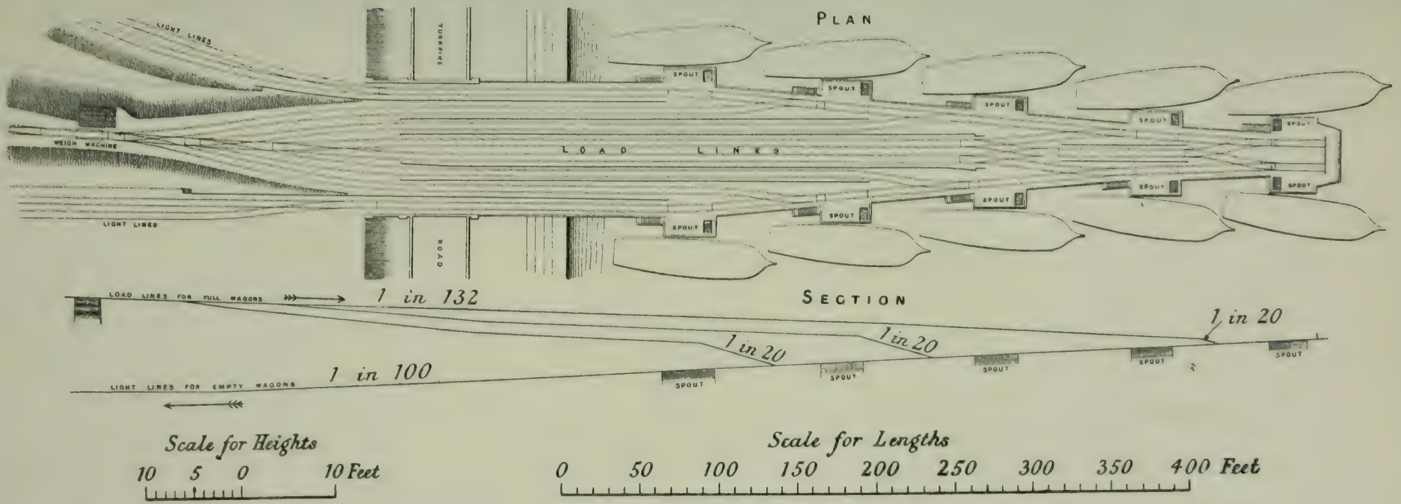
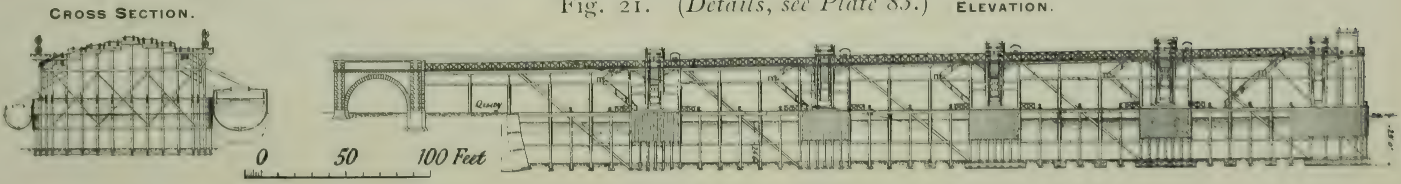
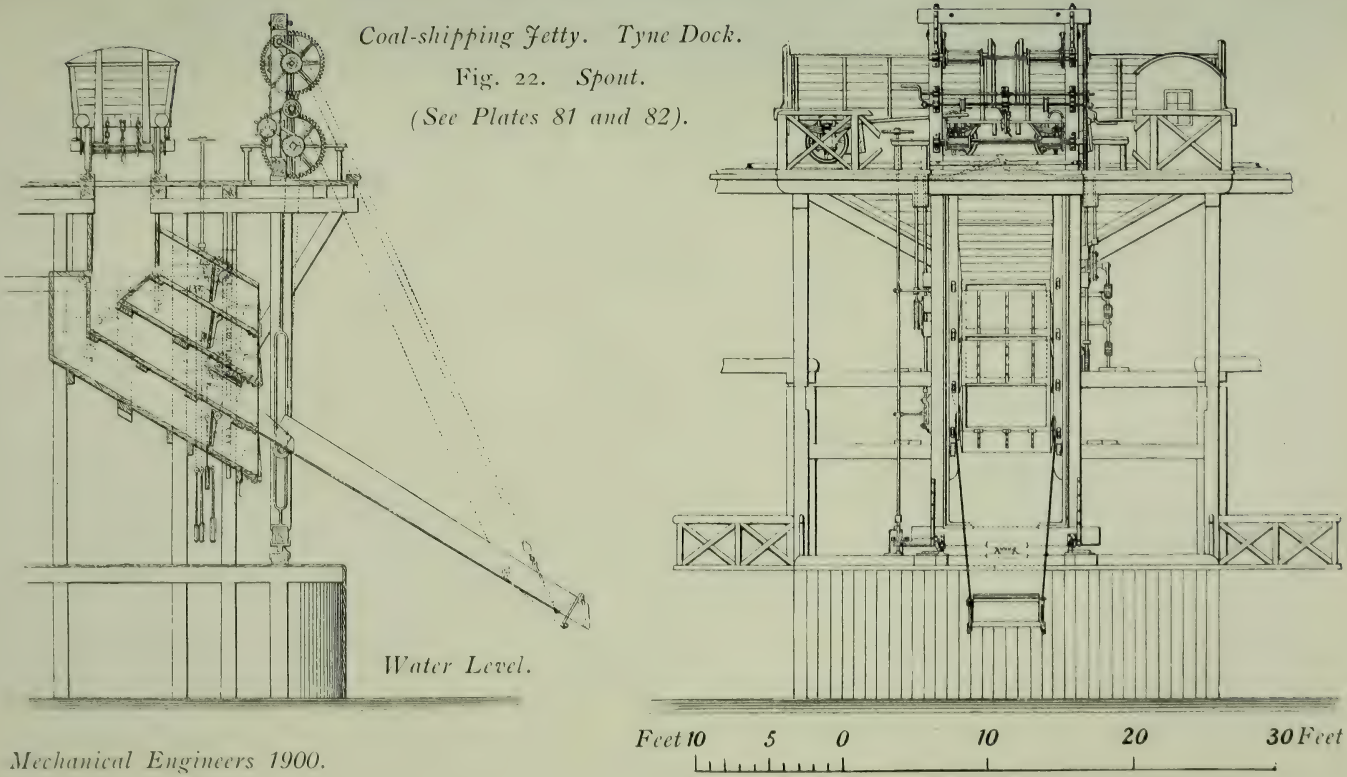


Fig. 21. (*Details, see Plate 83.*)





Coal-shipping Jetty. Tyne Dock.

Fig. 22. *Spout.*

(See Plates 81 and 82).

CAPACITY OF RAILWAY WAGONS. *Plate 84.*

Fig. 23. *Coaling Staith with Haulage Mule (American).*

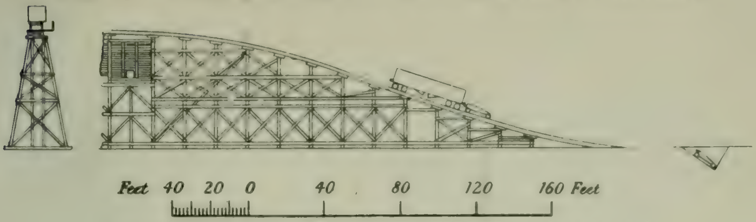


Fig. 24. *American Tip for 40 ft. Cars (McMyler).*

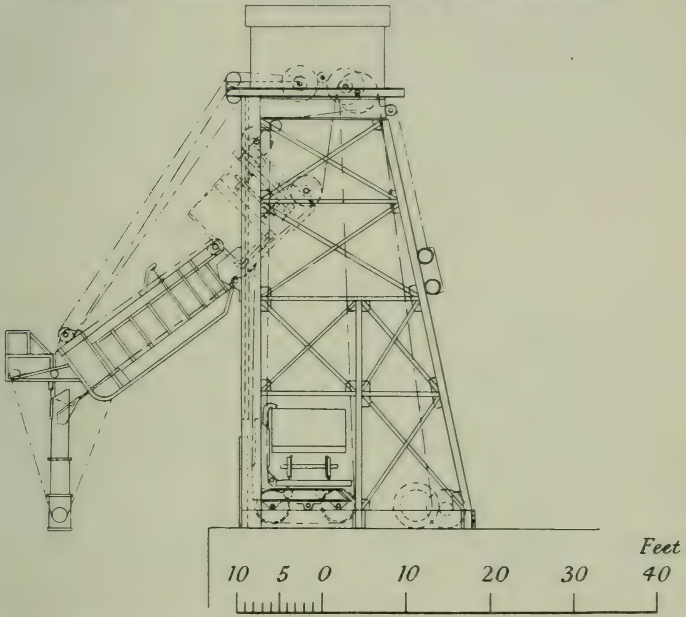
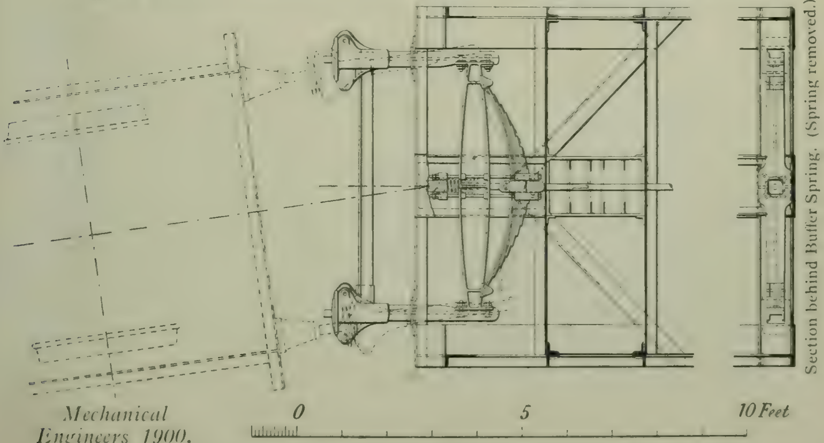


Fig. 25. *40-ft. Bogie Wagon on 4 Chain Curve.*

The dotted lines show position of Self-adjusting Buffers meeting Standard 10-ton Wagon.



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(Mr. Jepson's and Mr. Jones's Communications).

Fig. 26. *Bogie with Fox's Pressed Steel Frames, for 30 and 50-ton Wagons.*

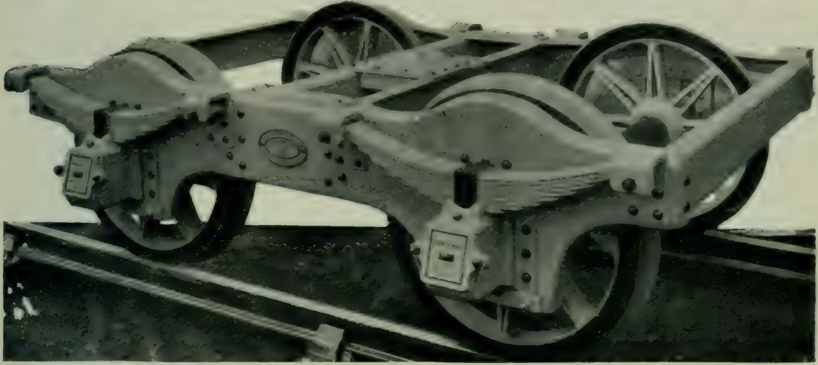


Fig. 27. *30-ton Coal Wagon, with Fox's Pressed Steel Frames.*

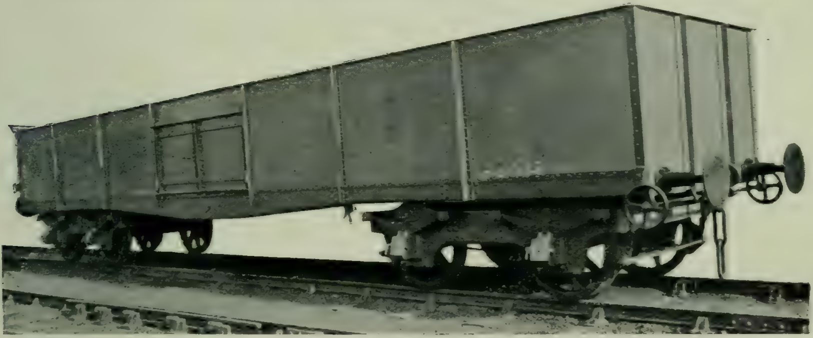
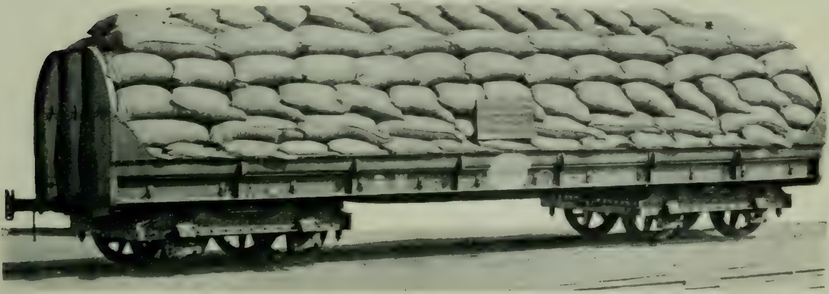


Fig. 28. *17-ton Wagon, Rajputana-Malwa Railway.*
(Tare 5 tons.)



(Mr. Jones's Communication.)

Fig. 29. *18-ton Steel Wagon, Rajputana-Malwa Railway.*
(Tare 6 tons.)

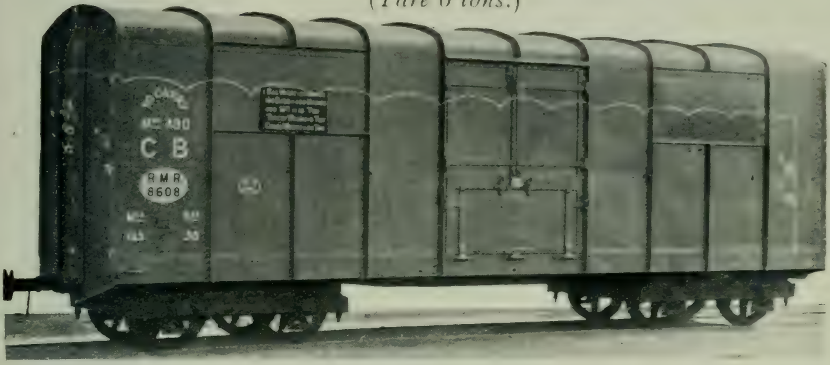
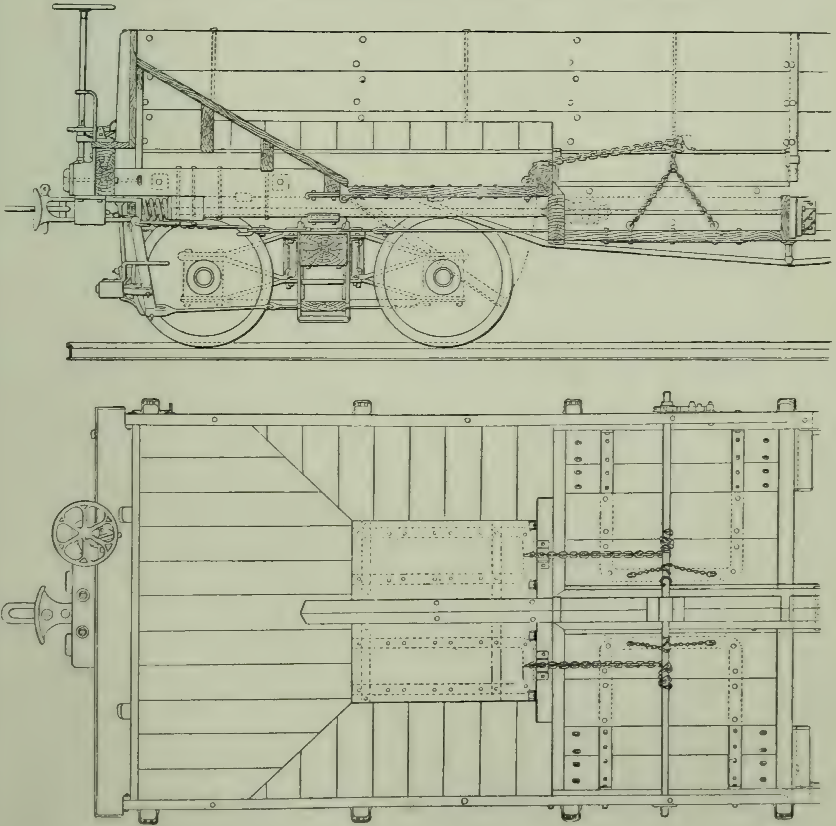


Fig. 30. *Coal Car, to carry 40,000 lbs. (American).*



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